COMPARATIVE EVALUATION OF THE EFFECT OF SPLINTING MATERIALS WITH IMPLANT IMPRESSIONS ON ALL- ON- FOUR TREATMENT PROTOCOL - AN *IN VITRO* STUDY

Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH I

PROSTHODONTICS AND CROWN & BRIDGE

MAY 2019

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled "COMPARATIVE EVALUATION OF THE EFFECT OF SPLINTING MATERIALS WITH IMPLANT IMPRESSIONS ON ALL–ON-FOUR TREATMENT PROTOCOL - AN *IN VITRO* STUDY" is a bonafide and genuine research work carried out by me under the guidance of **Dr. KAMAKSHI V, M.D.S., Reader,** Department of Prosthodontics and Crown & Bridge, Ragas Dental College and Hospital, Chennai.

Dr. JENSY SARA GEORGE
Post Graduate Student
Department of Prosthodontics
and Crown & Bridge
Ragas Dental College and Hospital,
Chennai

Date: 08.02.2019

Place: Chennai

CERTIFICATE

This is to certify that the dissertation titled "**COMPARATIVE EVALUATION OF THE EFFECT OF SPLINTING MATERIALS WITH IMPLANT IMPRESSIONS ON ALL-ON-FOUR TREATMENT PROTOCOL - AN *IN VITRO* STUDY**" is a bonafide record work done by **Dr. JENSY SARA GEORGE** under our guidance and to our satisfaction during her post graduate study period between **2016 – 2019.**

This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY**, in partial fulfillment for the Degree of **MASTER OF DENTAL SURGERY – PROSTHODONTICS AND CROWN & BRIDGE, BRANCH I.** It has not been submitted (partial or full) for the award of any other degree or diploma.

RAGAS DENTAL COLLEGE ★ Chennai

Guided by:

Kamakshi V

Dr. Kamakshi V, M.D.S.,
Reader
Department of Prosthodontics and Crown & Bridge
Ragas Dental College & Hospital,
Chennai.

READER
DEPT. OF PROSTHODONTICS AND CROWN & BRIDGE
Ragas Dental College & Hospital
Chennai - 600 119.

08/02/2019

Dr. N.S. Azhagarasan, M.D.S.,
Principal, Professor and Head
Department of Prosthodontics and Crown & Bridge
Ragas Dental College & Hospital,
Chennai.

Dr. N.S. AZHAGARASAN, MDS.
PRINCIPAL AND PROFESSOR & HOD,
DEPARTMENT OF PROSTHODONTICS AND CROWN & BRIDGE
RAGAS DENTAL COLLEGE AND HOSPITAL
2/102, EAST COAST ROAD, UTHANDI,
CHENNAI-600 119.

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY
CHENNAI

PLAGIARISM CERTIFICATE

This is to certify the dissertation titled "COMPARATIVE EVALUATION OF THE EFFECT OF SPLINTING MATERIALS WITH IMPLANT IMPRESSIONS ON ALL-ON-FOUR TREATMENT PROTOCOL - AN *IN VITRO* STUDY" of the candidate **Dr. JENSY SARA GEORGE** for the award of Degree of **MASTER OF DENTAL SURGERY** in **BRANCH I - PROSTHODONTICS AND CROWN & BRIDGE.**

On verification with the urkund.com website for the purpose of plagiarism check, the uploaded thesis file contains from introduction to conclusion pages shows **1%** of plagiarism, as per the report generated and it is enclosed in Annexure – IV.

Date: 08.02.2019

Place: Chennai

Jensy SG

Dr. Jensy Sara George
Post Graduate Student
Department of Prosthodontics and
Crown & Bridge
Ragas Dental College & Hospital,
Chennai.

Kamakshi V

Dr. Kamakshi V, M.D.S.,
Reader
Department of Prosthodontics and
Crown & Bridge
Ragas Dental College & Hospital,
Chennai.

READER
DEPT. OF PROSTHODONTICS
AND CROWN & BRIDGE
Ragas Dental College & Hospital
Chennai - 600 119.

RAGAS DENTAL COLLEGE & HOSPITAL

(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai

2/102, East Coast Road, Uthandi, Chennai - 600 119. INDIA.
Tele : (044) 24530002, 24530003-06. Principal (Dir) 24530001 Fax : (044) 24530009

TO WHOMSOEVER IT MAY CONCERN

Date: 03.01.2019

Place: Chennai

From

The Institutional Review Board,

Ragas Dental College And Hospital,

Uthandi, Chennai -600119.

The Dissertation topic titled "Comparative Evaluation of effect of splinting materials with implant impression on all-on-four treatment protocol- An invitro study" submitted by Dr. JENSY SARA GEORGE, has been approved by the Institutional Review Board of Ragas Dental College and Hospital.

Dr. N. S. AZHAGARASAN, M. D. S.,

Member Secretary,

Institutional Ethics Board,

Ragas Dental College and Hospital,

Uthandi, Chennai – 600119

ACKNOWLEDGEMENT

This dissertation has been kept on track and been seen through to completion with the support and encouragement of numerous people. I take this opportunity to thank all those people who contributed in many ways to the success of this study and made it an unforgettable experience for me.

I am deeply indebted to ***Professor Dr.N.S.Azhagarasan,M.D.S., Head of the Department,*** *Department of Prosthodontics and Crown & Bridge, Ragas Dental College and Hospital, Chennai, for his conscientious encouragement, solicitude inspiration and constant motivation. His stimulating suggestions in improvising the methodology with adequate scientific evidence need a special mention. I am extremely grateful that he has guided me and has provided heartfelt support throughout my postgraduate programme which has always driven the best out of me. This work would not have been possible without his exceptional guidance and with his personal attention. His unflinching courage and conviction will always inspire me.*

I would like to express my sense of respect, gratitude and thanks to my ***Guide, Dr. Kamakshi V, M.D.S., Reader*** *for her guidance, constant support, backup and valuable criticism extended to me during the period of my study. Her patience and perseverance had benefitted me in every facet of my study. The timely help and encouragement rendered by her had been enormously helpful throughout the period of my postgraduate study. I thank her wholeheartedly and wish her success and happiness in all her further endeavors. Thank you ma'am!*

I am also extremely indebted to ***Professor Dr.S.Jayakrishnakumar M.D.S.,*** *for his guidance and valuable criticism which provided a smooth basis for the progress of the study. I take this opportunity to say heartfelt thanks for the timely help without which my research would not have been possible.*

I would also like to thank ***Dr. M. Saravana Kumar, M.D.S., Dr. Hariharan R, M.D.S., Dr. Vallabh Mahadevan, M.D.S., Dr. Hariharan R, M.D.S., Dr. Vidya, M.D.S., Dr. Mahadevan, M.D.S.,*** *for their valuable suggestions and help given throughout my study.*

I would like to thank ***Mr. Prabhaharan****, Lab Technician of Tespa for helping me with CMM testing analysis. I would like to thank to* ***Mr. Ravanan,*** *Chennai, for helping me with statistical analysis used in invitro study.*

This journey would not have been possible without the support of my family. I am especially grateful to my parents ***Mr. George Samuel and Mrs. Lissy George*** *who supported me emotionally and financially. Special thanks to my sister* ***Mrs. Jenu Cherian*** *for her help, generous love and constant source of encouragement & my brother* ***Mr. Jevin George*** *for his encouragement and support.*

It would not be justifiable on my part if I do not acknowledge the help of my seniors ***Dr. Ashwini Sukanya GU, Dr. Sethu Raman, Dr. Gayathree, Dr. Revathi,*** *my juniors* ***Dr. Aishwarya, Dr. Tejaswini, Dr. Vaishali,*** *and my fellow postgraduates* ***Dr. Kowtham Raj, Dr. Arjun Badimela, Dr. Maniamuthu, Dr. Manimala, Dr. Asish M and Dr. Samin*** *for their continuous help, and support throughout my postgraduate course.*

I would like to thank ***Scribbles team*** *for their effort in the last minute printing, binding and his valuable time to submit the final dissertation copy.*

Last but not the least; I thank Almighty for the blessings, courage and grace endowed upon me.

CONTENTS

LIST OF TABLES

ANNEXURE I

METHODOLOGY – OVERVIEW

ANNEXURE II

LIST OF FIGURES

ANNEXURE III

LIST OF GRAPHS

BAR GRAPHS FOR INTER IMPLANT DISTANCES IN X, Y AND Z AXES AND INTER IMPLANT ANGULATION IN Z-AXIS

ANNEXURE – IV

PLAGIARISM REPORT

Introduction

INTRODUCTION

Rehabilitation of complete or partially edentulous arches using dental implants has become a standard clinical procedure with paramount success rate of 90% - 95% at 10 years survival rate. Implants have thus become a predictable long term treatment modality to the alternate conventional prosthesis in modern day clinical practice. [122,128]

A major sequel of tooth loss observed is irreversible alveolar bone resorption where significant alterations were noticed in height of body of mandible, loss of occlusal vertical dimension, resorption of anterior surface of condyle, reduction in coronoid process and width of ascending ramus. An average rate of residual ridge resorption (RRR) witnessed was four times greater in mandible than maxilla.[19,30,37]Depending on the quantity and quality of available maxillary and mandibular bone, dental restorative procedures such as root-supported implants, fixed dentures, or removable dentures can be planned. To maintain the bone in their normal physiologic levels, roots or fixed analogues like implants are required to simulate the internal loading of the available bone.[26,62]

Conventional dentures snugly fit over the soft tissues to provide upper or lower set of teeth. Among the various torments with patients using conventional prosthesis, discomfort, sore spots, poor stability and retention, poor masticatory force are most common[95] Rehabilitation with implant supported restorations owing to the increased awareness, demand, survival, and success has shifted the options for restoring the missing arch or teeth with implants, added with benefit of aesthetics, improved retention, stability,[58,88] phonetics, and masticatory efficiency[104,118]without any discomfort and better lifestyle.[52,74] The earlier loss of posterior tooth compared to the anteriors results in uneven resorption of the arch with posterior region being resorbed more and at a faster rate. In such clinical situations with less available resorbed bone, implant supported prosthetic treatment is almost impossible without additional techniques such as sinus lifting, nerve transposition, and grafting in the posterior maxilla and mandible.

Tilting of multiple implants such as "All–on–4" treatment concept was introduced for some clinical situations with less available resorbed bone, allowing better anteroposterior spread and also avoiding the anatomical structures. The "All-on- 4"protocol maximises the use of available bone of atrophic jaws, allowing immediate function, and thereby preventing complex procedures increasing the treatment cost and patient morbidity. The "All-on-4" concept was established by Paulo Malo[87] with straight and angled multi-unit abutments, to provide edentulous patients with an immediately loaded full arch restoration with only four implants. Two placed vertically in the anterior region and two placed up to an angle of 45° in the posterior region of the edentulous arch with longer implants.[5,7,9,41,97]

Tilting of posterior implants in mandibular arch, makes it promising to achieve good bone anchorage without involving the mental foramina and mandibular nerve. In extreme cases of severely resorbed maxillary bone, tilted implants are an alternative to sinus floor augmentation. A surgical guide is used as a platform in facilitating proper surgical placement and angulation of dental implants according to the treatment plan. [53,122]

Angulated implants in such situations are corrected with multiunit abutments so that the prosthesis have single path of insertion. The angled abutments can vary from 17° to 35° angulation to compensate the lack of parallelism between implants. Straight or 17° abutments are used in anterior implants and 30° in the posterior implants. Literature shows that stress patterns around implants placed at 15 and 30 degrees angle is comparable and when compared to the usage of axial implants with distal cantilevers, distal tilting of implants splinted by fixed restorations are biomechanically superior.

Each step in implant prosthodontics including treatment plan, impression making and up to fabrication of a passively fitting framework plays a vital role in achieving a predictable outcome.

In 1983, Branemark[31] was the first to define the *passive fit* stating that implant–bone interface or strain free superstructure should provide absolute zero strain on the supporting implant components and the surrounding bone in the absence of an applied external load[12,73,113] Several strategies have been suggested to reduce the distortion of implant framework with the help of laser welding[69,110] and electric-discharge welding.[77,83,114,135] If the passivity is not obtained, the framework misfit may lead to mechanical and biological complications. Mechanical complications such as loosening of prosthetic retained screws or the abutment screw, fracture of abutment screw and biological complications such as adverse tissue reaction, pain, marginal bone loss and even loss of osseointegration which was witnessed leading to primary instability.[73]

The first stage in achieving accurate, passively fitting prosthesis is reproducing the intraoral relationship of the fixtures with an impression. Currently, each implant system has its own set of machined impression copings that connect to the implant to transfer the position of the implant to a stone cast. The procedure differs significantly from conventional crown and bridge techniques because the critical aspect of the implant impression procedure is to maintain the position of the copings as they occur orally rather than reproducing surface detail.[25] Accurate working casts are essential to fabricate passively fitting implant prostheses. For the fabrication of these accurate casts, Implant impressions play a significant role; depending on the type of the material, impression technique and the accuracy of die material.[53,135] Literature and practical analyses shows that the open tray impression technique is more accurate compared to closed tray impression technique in cases of unfavorable implant angulations, multiple impressions or long span implant prosthesis.[24,57] However, the lack of parallelism and rotational distortional between impression copings during impression making may generate an inaccurate model.[53] Splinting the open tray impression copings with a rigid material is found to give most accurate casts compared to non-splinting of impression copings.[13,67,130,131] Thereby, the need to evaluate the positional accuracy of multiple implants on definitive casts using various splinting materials comes into highlight.

Over the years, various resin and non-resin materials have been used for splinting impression copings. Prefabricated acrylic resin bars, addition silicone,[66] bite registration addition silicone,[59]bite registration polyether,[59] bite registration polyvinyl siloxane,[80]stainless steel pins[93], metal shank of right-angle burs reinforced with cyanoacrylate,[48]metal cylinders,[89.]plastic rods combined with resin[116] and impression plaster have been used as splinting materials. The use of these materials for splinting has shown lot of variations and errors such that these variations have been partly due to the polymerization shrinkage of resin and setting expansion of impression plaster. Protemp IV[115], preformed composite bars,[47] flowable composite[71] also been used as splinting material to hold the impression copings together rigidly during impression making. Studies evaluating the efficacy of a recent generation of super low flowable composite as a splinting material are lacking. Moreover the use of orthodontic wire reinforced with pattern resin[63,84] has also been described in literature but the use of wire affixed to impression coping with bonding agent as a splinting material is not evident. Thus, there is a highlighted need to compare the efficiency of various newer splinting materials in achieving multiple implant impression which is cost effective and time efficient in a clinical set up.

The properties of the impression material have also been shown to influence the accuracy of the impression and the resultant cast.[135]Several impression materials have been used for multiunit implant impression; the most commonly described were Vinyl Siloxanether (VSE), Polyvinylsiloxane (PVS) and Polyether (PE) impression materials. Of all these materials', various literature have advocated the use of Polyether impression material as a standard material for performing accurate results comparing with other variables such as impression technique and implant angulation.[3,14,15,16,57,59,81,98,102,123,130,131,133]

There is a lot of controversy regarding the technique of impression making to be followed for obtaining an accurate multi-unit impression technique for complete edentulous situation. There are many studies comparing the different splinting materials, splinting techniques, three dimensional distortion of the implant level impression, effect of rotational distortions during impression making and the tolerances between different implant components. It is a necessity for the prosthesis to be fabricated on the working cast that reproduces, as accurately as possible the positioning of the abutments intraorally.

Former studies have evaluated the inter implant distances variation in one or two axes in the cast retrieved from the impressions.[17,56,71,115,130,135] There are very few studies which combined evaluation of the inter implant distances in casts, in x, y and z axes as well as the inter-implant angulations.[2,23,24,53,59,92,110] Therefore, there is a need to analyse and understand the impression technique and splinting material that best suits the requirements in a clinical scenario to achieve the three dimensionally accurate working casts for the fabrication of passively fitting implant framework.

Hence this in vitro study was aimed to compare the effect of splinting materials with implant impressions on *All- on- four* treatment protocol. The objectives of the present study were:

- To evaluate the effect of floss reinforced with pattern resin splinted open tray impression copings on the accuracy of implants transfer on master casts in x, y & z axes and inter implant angulations in z-axis for an *All-on-four* treatment protocol.
- To evaluate the effect of floss reinforced with super low flow flowable composite splinted open tray impression copings on the accuracy of implants transfer on master casts in x, y & z axes and inter implant angulations in z-axis for an *All-on-four* treatment protocol.
- To evaluate the effect of orthodontic wire affixed with bonding agent splinted open tray impression copings on the accuracy of implants transfer on master casts in x, y & z axes and inter implant angulations in z-axis for an *All-on-four* treatment protocol.
- To compare the effect of splinting materials with implant impressions on the accuracy of implants transfer on definitive casts in x, y & z axes and inter implant angulations in z-axis for an *All-on-four* treatment protocol

Review of Literature

REVIEW OF LITERATURE

Carr *et al*[38] (1992) compared the accuracy of working casts produced from impression technique for a two-implant 15 degree divergent posterior mandibular model. In this study, the comparison of direct and indirect impression technique was evaluated. Both techniques provided comparable results with average mean distortion. Critical analysis showed direct coping transfer technique giving better results than direct coping transfer in master cast fabrication.

Barrett *et al*[25] (1993) evaluated six impression techniques using square and tapered impression copings. In this study, eight impressions were made from each six impression techniques. Absolute Distortion analysis was done using the cast metal impression tray with fiduciary reference points external to impression material. Measurements of x, y and z coordinates on the master cast and impressions were made directly with a travelling digitizing microscope and compared. No significant differences were reported.

Hsu *et al*[63] (1993) compared four different implant transfer techniques using two master cast systems i.e, solid cast and Zeiser system where abutment positions were replicated. The techniques employed were non-splinted; splinted with dental floss and acrylic resin, splinted with orthodontic wire and acrylic resin and splinted with acrylic resin alone. Zeiser system showed more accurate inter abutment relationship than solid cast though there was no statistical significant difference.

Assif *et al*[13] (1999) evaluated the accuracy of three implant impression techniques using three different splinting materials in a laboratory model. The three materials used were autopolymerising acrylic resin to splint transfer copings, a dual cure acrylic resin and plaster. A metal implant master cast with an implant master framework was made to accurately fit the cast. The accuracy of each cast with the implant analogues was measured against the metal framework using strain gauge. The study concluded with autopolymerising acrylic resin or impression plaster as a splinting material was more accurate than dual cure acrylic resin.

Naconecy *et al*[93] (2004) studied the deformation of metallic framework connected to fifteen stone casts using three transfer techniques to determine the most accurate procedure. Five stone casts were made from polyether impression of an epoxy resin model. Three group samples of impression copings were splinted with carbon steel pins and autopolymerising resin, direct non splinted technique and indirect technique respectively. The carbon steel pins and autopolymerising resin showed accurate results compared to the other two techniques. The direct splinted technique was the most accurate transfer method for multiple abutments compared to direct non splinted and indirect techniques.

Vigolo *et al*[131] (2004) evaluated the accuracy of three impression techniques using polyether impression to obtain a precise working casts for a multi-unit implant restoration with internal connection implants. A reference acrylic model was used in which internal implant connection were fabricated. Three groups of 15 specimens were made with non-modified square impression copings, square impression copings joined together before impression procedure, square impression copings joined together with autopolymerising acrylic resin before impression & last, impression copings airborne particle abraded and coated with adhesive. The positional accuracy of the replicas were analysed and compared. The results show that the resin group showed more accuracy than the other two groups where the square impression copings were joined together with autopolymerising acrylic resin to make an impression of multiple internal implant connection.

Conrad *et al*[44] (2007) studied the accuracy of two impression techniques with angulated implants. In this study, one definitive cast was fabricated for six experimental groups and one control group. In all these casts, three implants were arranged in a triangular pattern creating a plane where the middle implant was perpendicular to the plane while the other implants had 5, 10 and 15 degree convergence or divergence away from the centre implant. Five open tray and five closed tray addition silicone were made of each definitive casts. Impressions were poured in type IV dental stone. A fine measuring stylus tip was used to record multiple axis in x, y and z coordinates on top of implant hex. The angle errors for both open and closed impression techniques had no significance. Magnitude of distortion was the same for all impression technique and angulation and number.

Filho *et al*[56] (2009) compared splinting techniques for impression copings of osseointegrated implants with different angulations. Metal matrix containing two implants at 90º and 65º were obtained using four impression techniques. Direct technique with square copings without union in open trays, second technique with square copings splinted with dental floss and autopolymerising resin, third being square copings splinted with dental floss and autopolymerising resin, sectioned and splinted again with autopolymerising resin and the fourth one being square copings splinted with prefabricated acrylic resin bar. The results of this study showed square copings splinted with prefabricated acrylic resin bar gives the best results.

Assuncao *et al*[17] (2010) compared the two splinted impression transfer techniques for implant supported prostheses. A metal matrix was used to place implants positioned at 90°, 80°, 75° and 65° in relation to the surface of the matrix. Square impression copings were splinted with self-curing acrylic resin (n=10) and condensation silicone in second group (n=10). In this study, computer software was used to measure the implant analogues inclinations. No statistically significant differences seen in groups compared to the control group except for 75 degrees implant analog inclinations. The findings of this study concluded splinting with acrylic resin did not present significant difference from control group, whereas splinting with condensation silicone differed from control group. Implant inclination affect impression accuracy if it's beyond inclination.

Hariharan *et al*[59] (2010) evaluated the accuracy of multiple implant impressions using various splinting techniques non-splinting, acrylic resin, bite registration addition silicone and last, bite registration polyether. In this study, a reference model with four implant replicas in the anterior mandible was fabricated with heat curing acrylic resin. Impressions were made using polyether impression material by direct non – splinted and splinted technique & cats were poured. Linear differences in inter-implant distances and angulations in the cast were measured using coordinate measuring machine. The study concluded that cast obtained using bite registration polyether splinted technique were accurate, followed by acrylic resin splinted, non-splinted & bite registration addition silicone-splinted techniques.

Lee *et al*[80] (2011) evaluated the dimensional stability of splinting material on the accuracy of the master casts. A stainless steel model with 6 implant analogues embedded after square impression copings were splinted using autopolymerising resin and sectioned, reconnected to compensate polymerization shrinkage before the impression procedure; splinted with autopolymerising resin just before impression procedure; primary impression made with impression plaster and secondary made with polyether; splinted with plaster and fifth being splinted with VPS bite registration material. The study concluded with splinted square impression copings with autopolymerising resin that is sectioned, reconnected before the impression procedure showed accurate master casts and impression plaster can be used as simple and effective splinting material.

Ongul *et al*[98] (2012) compared the accuracy of different direct implant impression techniques for edentulous arches with multiple implants. In this study, five experimental groups were non-splinted technique, second and third splinted with acrylic resin bar and the last two being splinted with light curing composite resin bar. Out of the five models, third and the fifth one sectioned and rejoined. Distortion values were measured and found that acrylic bars showed less deviation from master model than light cured composite resin and non-splinted group.

Tarib *et a1*[125] *(*2012) evaluated the effect of splinting during implant impression where four techniques were used. In this study, a master model was used with two fixtures at sites 45 and 47. Twenty impressions were made using indirect technique, direct, unsplinted, direct splinted technique and direct, splinted, sectioned and re-splinted technique. Splinting was done with autopolymerising acrylic resin. Using digital caliper, horizontal distance between fixtures was compared & difference in distance were analysed with one way ANOVA. The findings of the study found to be group i.e., direct, splinted, sectioned and re-splinted to show more accuracy than the other groups giving a more beneficial accurate impression.

Kamrani *et al*[72] (2014) compared the accuracy of an open-tray implant impression technique using three types of splinting materials: a pattern resin, an acrylic resin, and a dual cured composite. Sixty impressions were made with 20/group. Implant positions were compared against the master model using CMM. Differences in X-axis were found with ANOVA comparison. The findings of the study concluded composite resin demonstrating better accuracy than the other tested splinting materials.

Beyabanaki*et al*[28] (2015) evaluated the effect of splinting on accuracy of impressions made of implants with different subgingival alignments. In this study, a metal model with two parallel implants was fabricated. 120 impressions were made using direct impression technique with and without splinting the impression copings at three subgingival levels 1, 3 and 6 mm using regular viscous polyvinylsiloxane. Displacements in the x, y and z-axes and rotational discrepancy were measured by coordinate measuring machine. Longer impression copings give better results than the shorter ones in splinted and non- splinted techniques. In addition, the non-splinted short impression copings produced more accurate impressions than splinted short impression copings.

Selvaraj *et al*[115] (2016) evaluated the accuracy of implant cast of multiple implant impression technique with different splinting materials, autopolymerizing resin and protemp TM 4 (bis-GMA) temporarization material. Ten custom trays were fabricated using the light curable resin sheets where medium body polyether was used to make impressions and casts were poured. The master casts were analyzed using coordinate measuring machine. The conclusion of the study stated that, both splinting materials exhibited no difference from the reference model. So, bis-GMA can be used for splinting as it is easy to handle, less time consuming, less technique sensitive, rigid and available in clinics.

Shankar *et al*[116] (2016) investigated the accuracy of implant impressions using open and closed impression techniques with polyvinylsiloxane, polyether and vinylsiloxanether on angulated implants. A stainless steel reference die with six analogs placed at 0º, 10º, 20º toward the center axis. Sixty samples of twenty custom trays were fabricated under each type of impressions. Two types of splinting were carried out in each group; floss with pattern resin and with a plastic rod (coffee stirrer) and resin. VSE yielded more accurate impressions than those of PVS and PE. The study also concluded that splinting with floss and pattern resin gave more accuracy than stirrer and resin.

Baig *et al*[23] (2018) assessed the accuracy of multi-unit implant casts obtained from vinyl polyether silicone and polyether, and also to test the effect of splinting of impression copings on the accuracy of casts. The groups were divided into four subgroups of five each, unsplinting, bite registration polyether, bite registration addition silicone, auto polymerizing acrylic resin. The study was concluded that VPES impression material seemed comparable with that of PE for multiunit implant abutment level impressions and also splinting had no effect on the accuracy of implant impressions.

Elshenaway *et al*[53] (2018) evaluated the cast accuracy obtained from different impression techniques at different implant angulations. Three Osseolink implants were placed in models with parallel, 15º and 30º. Three techniques were; indirect, unsplinted direct and acrylic resin splinted direct technique. Using CMM, the inter implant distances from the reference models were calculated. The findings of the study concluded with the acrylic resin splinted direct technique produced the most accurate casts, followed by direct unsplinted and indirect techniques. Furthermore, implant angulations affected the impression accuracy when increased from parallel to 30º resulting in increased distortion.

Thara *et al*[71] (2018) evaluated the positional accuracy in multiple implants in the cast using different splinting materials such as acrylic resin onto floss added, sectioned and rewelded, pattern resin, flowable composite, and bite registration material. Out of the four materials used, it was observed that all materials are equally in par with the conventionally used materials like acrylic and pattern resin.

Materials and Methods

MATERIALS AND METHODS

This *in vitro* study evaluated the effect of various splinting materials, namely, floss reinforced with pattern resin, floss reinforced with super low flow flowable composite and orthodontic wire affixed with universal bonding agent splinted open tray impression copings with implant impression transfer on definitive casts in an all-on-four treatment protocol.

The following materials, instruments and equipments were used in the present study:

MATERIALS:

- Implant analog (Pre-mounted, RP, Osstem Implant, Korea) (Fig. 1)
- Multiunit abutment (straight-TS, Ref TMA5020, Osstem, Korea) (Fig. 2)
- Multiunit abutment (17°- Hex, Ref GS17MAS4830WH, Osstem, Korea) (Fig. 3)
- Multiunit abutment (30°- Hex, Ref GS30MAS4830WH, Osstem, Korea) (Fig. 4)
- Open tray impression coping (Esthetic – low, Pick –up, Non-Hex, Osstem RP, Ref MSR100, Korea) (Fig. 5)
- Laboratory Analog (Esthetic – low Lab Analog, Osstem RP, RefMERR300, Korea) (Fig. 6)
- Modelling wax (The Hindustan Dental Products, India) (Fig. 7)
- Alginate Irreversible hydrocolloid impression material (Algitex, India) (Fig. 8)
- Type IV die stone (Dentcare, India) (Fig. 9)
- Light cure resin sheets (Individo Lux, Voco, Germany) (Fig. 10)
- Dental Floss (Waxed, Colgate, India) (Fig. 11)
- Autopolymerising pattern resin (GC Pattern Resin, Osaka, Japan) (Fig. 12)
- Flowable composite (Super Low, Palfique Universal Flow, Tokuyama Dental, Japan) (Fig. 13)
- Orthodontic wire (19 gauge) (Konark SS wire, India) (Fig. 14)

- Universal Bonding agent (Palfique Universal Bond, Tokuyama Dental, Japan) (Fig. 15)
- Polyether adhesive (3M ESPE, Germany) (Fig. 16)
- Polyether Impression material (Impregum soft, 3M ESPE, USA) (Fig. 17)

INSTRUMENTS USED IN THE PRESENT STUDY:

- Hex driver (Osstem Implant, Korea) (Fig. 18)
- Manual torque wrench (Osstem Implant, Korea) (Fig. 19)

EQUIPMENTS USED IN THE PRESENT STUDY:

- Physiodispenser (OSSTEM SM3 SL, Japan) (Fig. 20)
- Drilling kit (Osstem, Japan) (Fig. 21)
- Light curing unit (Polymat, Delta) (Fig. 22)
- Vibrator (220V, High power Investment vibrator, Korea) (Fig. 23)
- Coordinate Measuring Machine (TESA Microhite 3D, TESPA) (Fig. 24)

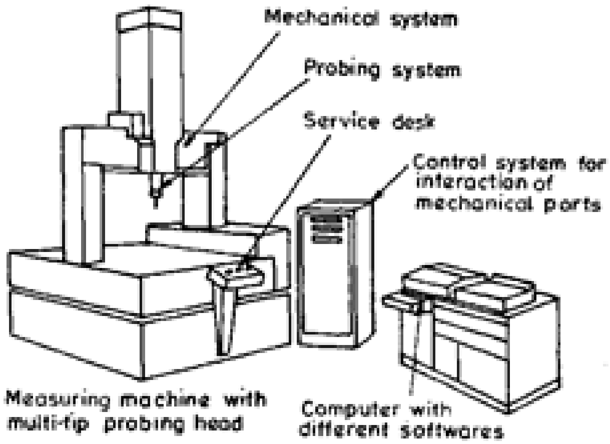
Description of Coordinate measuring machine (Fig. 25):

Coordinate measuring machine is a fine adjust device that uses point to point probing on the surface of an object with the probe. It has TESA-REFLEX MH3D software, and three probing heads. The machine incorporates the three coordinate axes so that precise movement in x, y, and z directions is possible. Each axis is fitted with a linear measurement transducer which senses the direction of movement and gives digital display of the readings.

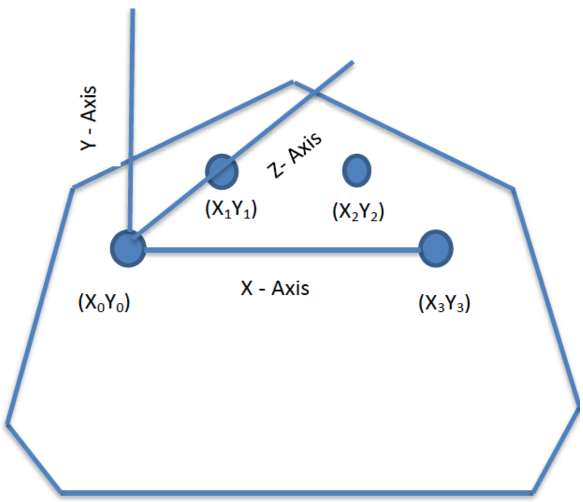
SPECIFICATION:

Fine adjust device	Yes
Displacement	Manual
Measuring volume (mm)	460 x 510 x 420
MPE_E (µm) (L in mm)	3 + 4L/1000
Overall dimensions (machine) L x P x H (mm)	970 x 930 x 1620
Software	TESA-REFLEX MH3D

LINE DIAGRAM OF COORDINATE MEASURING MACHINE



LINE DIAGRAM OF REFERENCE MODEL



METHODOLOGY

The methodology adopted for this study has been divided into the following sections:

I. Fabrication of reference model

a. Edentulous 3-D printed phototopic polymer model
b. 3-D printed Surgical guide for All-on-four treatment protocol
c. Surgical guide placed over the model
d. Implant analogs drilled according to guide
e. Reference model with four OSSTEM implant analogs positioned according to *All-on-four* treatment protocol
f. Multiunit abutments fastened to implant analogs
g. Open tray Impression copings attached to multiunit abutments

II. Fabrication of custom tray

a. Wax spacer adapted and blocked out
b. Alginate impression made out of spaced model
c. Primary cast prepared with Type IV die stone
d. Resin sheets adapted to spaced primary cast
e. Custom trays fabricated for each group (n=10 per group)

III. Final impressions

Group I- Splinting – Floss reinforced with pattern resin

Group II- Splinting – Floss reinforced with flowable composite

Group III- Splinting – Orthodontic wire affixed with universal bonding agent

IV. Obtaining master casts

V. Evaluation of reference model and master casts

Measuring the reference model and working casts using coordinate measuring machine

VI. Data tabulation and statistical analysis

DETAILED DESCRIPTION OF METHODOLOGY

I. FABRICATION OF REFERENCE MODEL

A reference phototopic polymer model (Dentcare, India) (Fig. 25) of the edentulous mandibular arch was fabricated by 3D printing and a standard photocurable acrylic resin surgical guide (Proto3D Solutions Pvt Ltd, India) (Fig. 26) was made by SLA 3D printing based on the All-on-four treatment protocol. Four Osstem implant analogs (Pre-mounted, RP, Osstem Implant, Korea) (Fig. 1) were drilled into the reference model (Fig. 27 b) according to the drilling protocol with the help of surgical guide positioned on the model. (Fig. 27 a) Two implant analogs were placed anteriorly and two distal implants tilted and placed posteriorly with the aid of surgical guide.

Four multiunit abutments (Osstem Implant system, Japan) (Fig. 4 to Fig. 6) were tightened to the implant analogs respectively. (Fig. 29) Two straight multiunit abutments (TS, RP, Ref TMA5020, Osstem, Korea) (Fig. 2) placed anteriorly and two multiunit abutments were placed posteriorly. One multiunit abutment 17 degree (Hex, RP, Ref GS17MAS4830WH, Osstem, Korea) (Fig. 3) was placed on one side and another 30 degree multiunit abutment (Hex, RP, Ref GS30MAS4830WH, Osstem, Korea) (Fig. 4) placed on the other side based on the implants position and straightened to a single path of insertion. (Fig. 29)

II. FABRICATION OF CUSTOM TRAY

Four squared open tray impression copings (Esthetic – low, Pick –up, Non-Hex, Osstem RP, Ref MSR100, Korea) (Fig. 5) were secured onto the reference model (Fig. 30) and tightened at a torque of 15Ncm using a hex driver (Osstem Implant, Korea) (Fig. 18) and a calibrated torque wrench (Osstem Implant, Korea) (Fig. 19). Using hard modelling wax (The Hindustan Dental Products, India) (Fig. 7), under cuts were blocked out and a uniform spacer of 3mm was incorporated in the reference model by adapting two layers of modelling wax. (Fig. 31) An alginate irreversible hydrocolloid impression (Algitex, India) (Fig. 8) was made of the spaced reference model (Fig. 32) and cast was poured using type IV dental stone (Dentcare, India) (Fig. 9) to obtain a spaced primary cast. (Fig. 33)

Light cure resin sheet (Individo Lux, Voco, Germany) (Fig. 10), 2mm in thickness was placed onto the spaced primary cast (Fig. 34) A window was created in the anterior region over the implant impression posts. Tray handles were attached on both sides posteriorly and one anteriorly. The adapted resin tray along with the cast was then placed in a light cure box (Polymat, Delta) (Fig. 22) and the resin sheet were cured for 6 minutes as per the manufacturer's recommendation. The tray was removed from the cast and again kept inside the light curing unit for another 6 minutes curing cycle. It was then removed and finished to an even thickness of 2mm (Fig. 34). In this manner, a total of 10 custom trays were made on the same cast to standardize the spacer thickness. (Fig. 35) All the trays were left undisturbed for 24 hours prior to impression making, for the trays to become dimensionally stable.

III. FINAL IMPRESSIONS

The custom trays that were obtained in the above manner were employed for impression making. For each group, ten custom trays were fabricated.

Impressions were divided into three groups: (Fig. 36 to Fig. 38)

Group I: Floss reinforced with pattern resin splinted technique

Group II: Floss reinforced with super low flow flowable composite splinted technique

Group III: Orthodontic wire affixed to impression coping with Universal bonding agent splinted technique

The procedure adopted for impression making for the above mentioned three groups is described in detail below.

Group I: Floss reinforced with pattern resin splinted technique (Fig. 36)

The open tray impression copings were fastened on to the multiunit abutments that are attached to the implant analogs at 15Ncm torque. (Fig. 30) In this method, the floss (Waxed, Colgate, India) (Fig. 11) was tied over the impression copings in a figure of eight. (Fig. 36 a) An index was made around the impression coping in the primary cast using putty consistency addition silicone to act as a scaffold for the splinting material. (Fig. 36 b) Auto polymerizing pattern resin (GC

Pattern resin, Osaka, Japan) (Fig. 12) was mixed according to manufacturer's instruction. When the resin reached the dough stage it was adapted around the floss (Fig. 36 b) which was secured to the impression copings. The resin was allowed to polymerize for 4 minutes and the putty index was removed. The custom tray and the open tray impression copings were coated with a uniform layer of Polyether adhesive (3M ESPE, Germany) (Fig. 16) and allowed to dry for fifteen minutes as per the manufacturer's recommendation. (Fig. 36 c) The impression copings with long handles were attached into the abutment analogs of the reference model at a torque of 15Ncm using the calibrated manual torque wrench. Medium body polyether (3M ESPE, USA) (Fig. 17) was hand mixed and loaded onto the tray (Fig. 36d) and between the impression copings to avoid impression defects around the copings. The tray was then placed over the reference model, seated completely with finger pressure and pressed equally for uniform flow of the impression material. Fig. 36e) The excess material that had flown over the top of the impression copings through the window in the custom tray was removed to expose the screws. (Fig. 36 f) The impression was allowed to set for six minutes as per the manufacturer's recommendation. The screws of the impression copings were unscrewed and impression was retrieved from the reference model. (Fig 36 g, h and i) To each impression coping on the intaglio surface of impression, laboratory analogs (Esthetic – low Lab Analog, Osstem RP, RefMERR300, Korea) (Fig. 6) were fixed. (Fig. 39) A total of ten impressions were made in this group in similar manner.

Group II: Floss reinforced with flowable composite splinted technique (Fig. 37)

The open tray impression copings were fastened on to the multiunit abutments that are attached to the implant analogs at 15Ncm torque. An index was made around the impression coping in the primary cast using putty consistency addition silicone to act as a scaffold for the splinting material. In this group, the floss was tied over the impression copings in a figure of eight. (Fig. 37a) Flowable composite of super low consistency (Super Low, Palfique Universal Flow, Tokuyama Dental, Japan) (Fig. 13) was used to reinforce the floss. (Fig. 37b) and light cured for 10 seconds. (Fig. 37c) The custom tray and the open tray impression copings were coated with a uniform layer of Polyether adhesive and allowed to dry for five minutes as per the manufacturer's recommendation. (Fig. 37d) The procedure of impression making followed was similar to that of Group I. (Fig. 37e to Fig. 37i)

Group III: Orthodontic wire affixed to impression coping with Universal bonding agent splinted technique (Fig. 38)

The open tray impression copings were secured on to the multiunit abutments that are attached to the implant analogs at 15Ncm torque. In this group, 19 gauge orthodontic wires (Konark SS wire, India) (Fig. 14) were sectioned and placed across the impression copings (Fig. 38a) and bonded with a Universal Bonding agent (Palfique Universal Bond, Tokuyama Dental, Japan) (Fig. 15). The bonding agent was dispensed into the mixing well and applied over the impression copings and sectioned wires and then air dried. (Fig. 38b) Adequate bond strength was tested with finger pressure and was found to be satisfactory as none of the wires dislodged with the finger pressure applied. The remaining part of the impression procedure was similar to that of Group I and II. (Fig. 38c to 38h)

IV. OBTAINING MASTER CASTS

The impressions made were allowed to polymerize completely for 15 minutes. To each impression coping on the intaglio surface of impression, laboratory analogs (Esthetic – low Lab Analog, Osstem RP, RefMERR300, Korea) were fixed. (Fig. 39) Casts were poured using type IV die stone (Dentcare, India) (Fig.9). The stone was hand mixed with water as per the manufacture recommended ratio of 100 gram to 20 ml and vibrated in a vibrator (220V, High power Investment Vibrator, Korea) (Fig. 23) to minimize incorporation of air bubbles. The same amount of dental stone was used for pouring all the casts and allowed to set for two hours. After complete setting, the casts were retrieved from each impression. Only one cast was poured in each impression. A total of 30 master casts from 30 impressions were thus obtained (10 casts per group) (Fig. 40).

V. EVALUATION OF REFERENCE MODEL AND MASTER CASTS

The casts obtained from the different impressions were grouped according to respective techniques and numbered from 1 to 10 in each group. The reference model and all the master casts were evaluated using a coordinate measuring machine

(TESA Microhite 3D, TESA Technology) (Fig. 26), which is capable of measuring in x, y and z axes with an accuracy of ±5µm (Fig. 41). The CMM was connected to a data processor which gave the measured values. In order to measure the three dimensional accuracy of the master casts, the inter implant distances in x, y and z axes were measured (Fig. 44 to Fig. 46) and the angle between the implant around the z axis (Fig. 47) were evaluated. The implants were numbered 1 to 4 starting from left posterior analog to the right posterior analog.

The probe used in the CMM was first calibrated. The reference model was measured to obtain the reference values. The model was secured in the base for measuring. In order to obtain similar orientation of the reference model and the entire master casts, the centre premeasured analog 1 and 4 were first aligned in the CMM and then the measurements were made.

The coordinates of the centre of the analog 1 was measured and zeroed. Keeping this position as a reference, the positions of the centres of the other 3 analog were measured. The linear distance between the centre of analog 1 and 2 (D1x/y), 1 and 3 (D2x/y), and 1 and 4 (D3x/y) were measured in the x and y axes. Then, the probe was used to measure the plane formed by the platform of abutment analog 1. Similarly, the distances formed by the three abutment analogs were measured. The distances between the planes formed by the abutment analogs 1 and 2 (D1z), 1 and 3 (D2z), and 1 to 4 (D3z) were measured to determine the inter implant distances in the z axis. (Fig. 45)

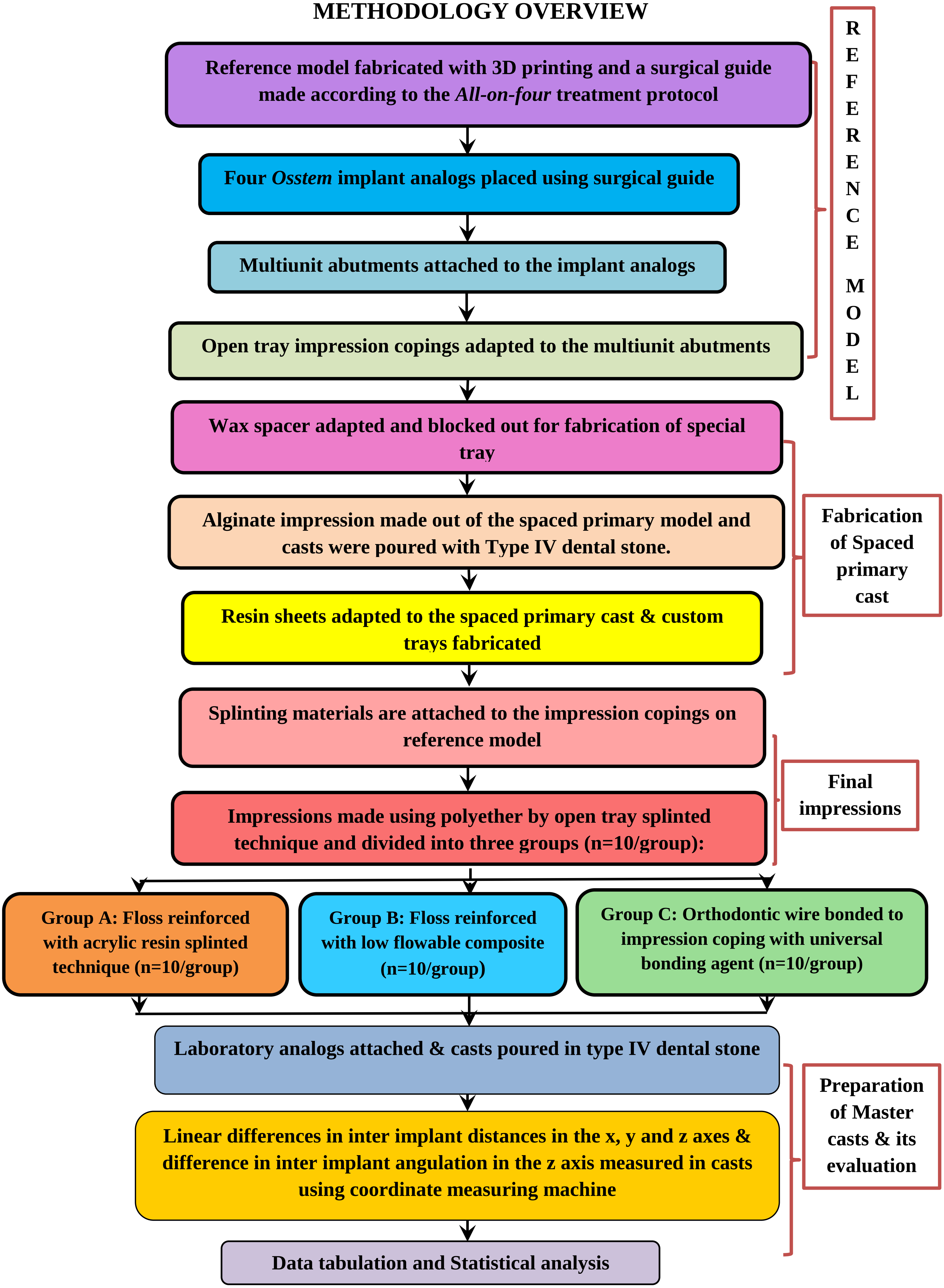
In order to find the angular relationship between the analogs, the open tray impression copings were connected to the implant analogs and screwed at 15Ncm torque. The plane formed by the flat surfaces of the impression copings were measured. The angle formed between the implant analogs 1 and 2. 1 and 3, and 1 and 4 were measured by calculating the angle formed by the flat surfaces of the respective impression copings. (Fig.46)

VI. DATA TABULATION AND STATISTICAL ANALYSIS:

The reference model was measured 5 times to get a mean value. All the master casts were measured using coordinate measuring machine and the measurements were made by a single operator to avoid inter operator error.

The mean values for each group were obtained and they were tabulated and subjected to statistical analysis by SPSS software (SPSS for windows 16.0 SPSS Corp., Germany). One sample T- test, One way ANOVA and Post- hoc Tukey's analysis were done to compare the data obtained for statistical significance with respect to inter implant distances in x- axis, y-axis and z-axis & inter implant angulation in relation to z-axis of the three test groups.

ANNEXURE –I
METHODOLOGY OVERVIEW



ANNEXURE – II

FIGURES

MATERIALS EMPLOYED IN THE PRESENT STUDY

Fig. 1: Implant analog

Fig. 2: Multiunit abutment (Straight)

Fig. 3: Multiunit abutment (17°)

Fig. 4: Multiunit abutment (30°)

Fig. 5: Open tray Impression coping

Fig. 6: Laboratory analog

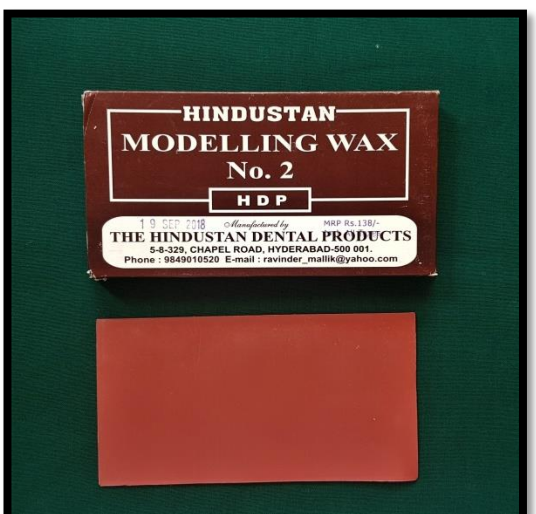


Fig. 7: Modelling wax

Fig. 8: Alginate Irreversible Hydrocolloid Impression material

Fig. 9: Type IV die stone

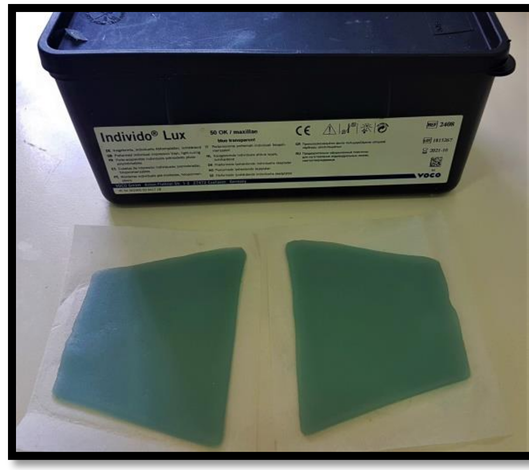


Fig. 10: Light cure resin sheets

Fig. 11: Dental floss

Fig. 12: Autopolymerising pattern resin

Fig. 13: Flowable composite (Super Low flow)

Fig. 14: Orthodontic wire (19 gauge)

Fig. 15: Universal Bonding agent

Fig. 16: Polyether adhesive

Fig. 17: Polyether impression material

INSTRUMENTS USED IN THE PRESENT STUDY:

Fig. 18: Hex driver

Fig.19: Manual Torque wrench

EQUIPMENTS USED IN THE PRESENT STUDY

Fig. 20: Physiodispenser (OSSTEM Implants)

Fig. 21: Drilling Kit (OSSTEM Implants)

Fig. 22: Light curing Unit

Fig. 23: Vibrator (220V)

Fig. 24: Coordinate measuring machine (CMM)

METHODOLOGY

I. FABRICATION OF REFERENCE MODEL

Fig. 25: Edentulous 3D printed phototopic polymer model

Fig. 26: 3D printed surgical guide for All-on-four treatment protocol

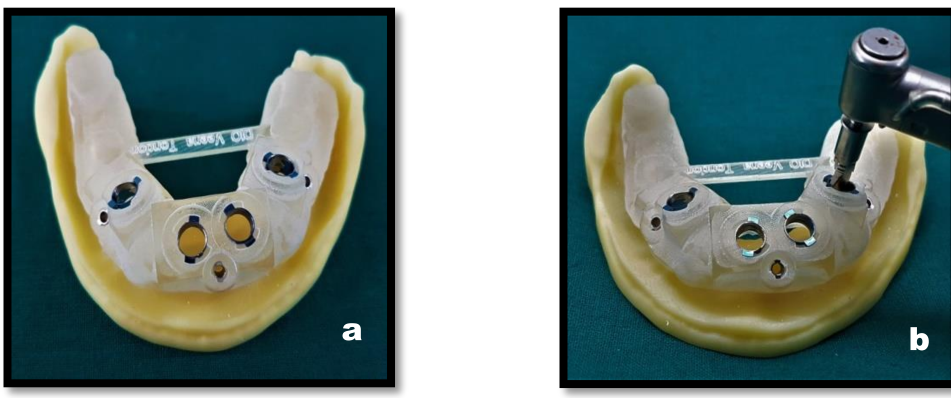


Fig. 27(a): Surgical guide placed over the model
Fig. 27(b). Implant analogs drilled according to guide

Fig. 28: Reference model with four OSSTEM implant analogs positioned according to *All-on-four* treatment protocol

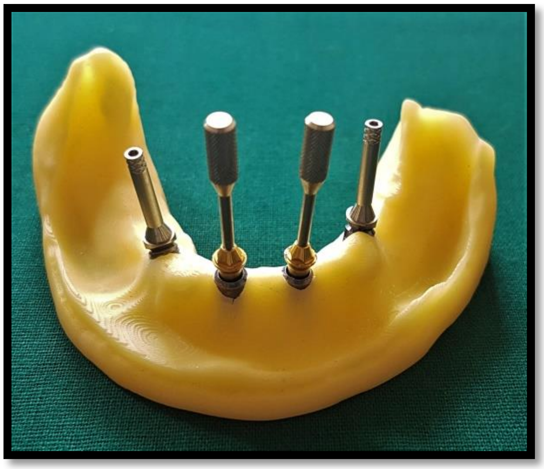


Fig. 29: Multiunit abutments fastened to implant analogs

Fig. 30: Open tray impression copings attached to multiunit abutments

II. FABRICATION OF CUSTOM TRAY

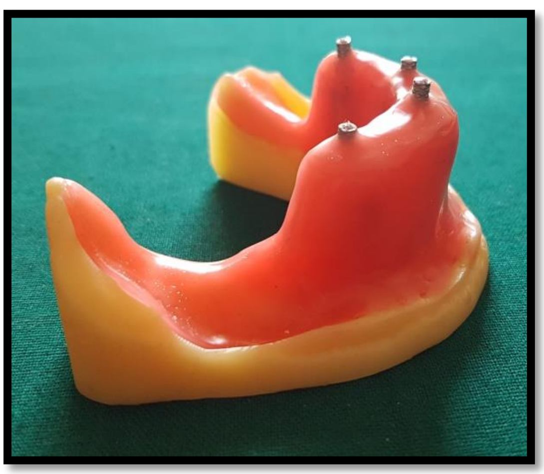


Fig. 31: Wax spacer adapted and blocked out

Fig. 32: Alginate impression made out of spaced model

Fig. 33: Primary cast prepared with Type IV die stone

Fig. 34: Resin sheets adapted to spaced primary cast

Fig. 35: Custom trays fabricated for each group (n=10 trays/test group)

III. FINAL IMPRESSIONS

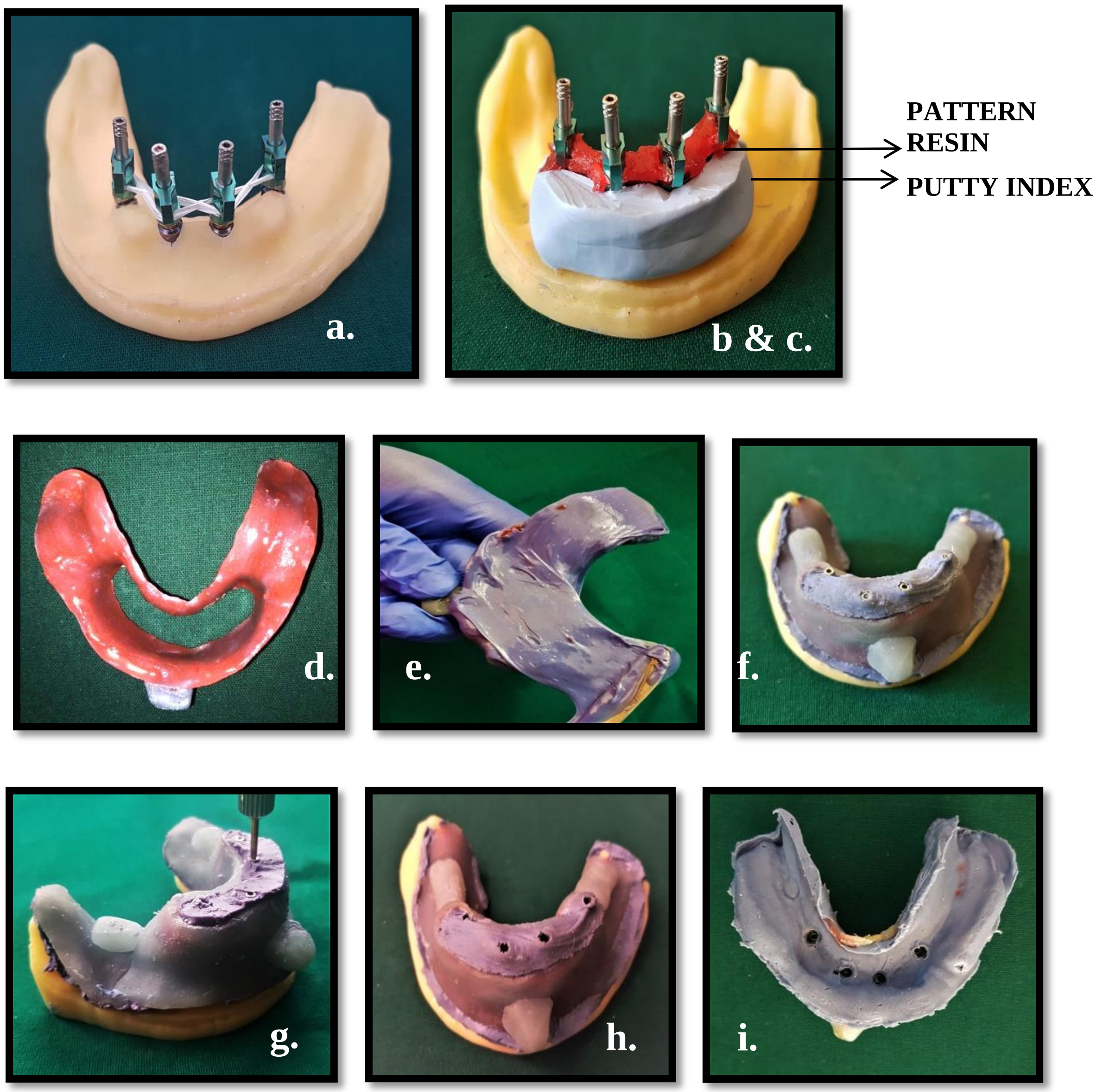


Fig. 36: Group I – Splinting -Floss reinforced with pattern resin

a) Floss tied between impression copings in 8-figure **b)** Fabrication of putty index to act as a scaffold for splinting **c)** Floss reinforced with pattern resin **d)** Application of polyether adhesive **e)** Loading the tray with polyether impression material **f)** Completely seated impression with excess removed **g & h)** Unscrewing of long handles **i)** Completed impression showing the intaglio surface

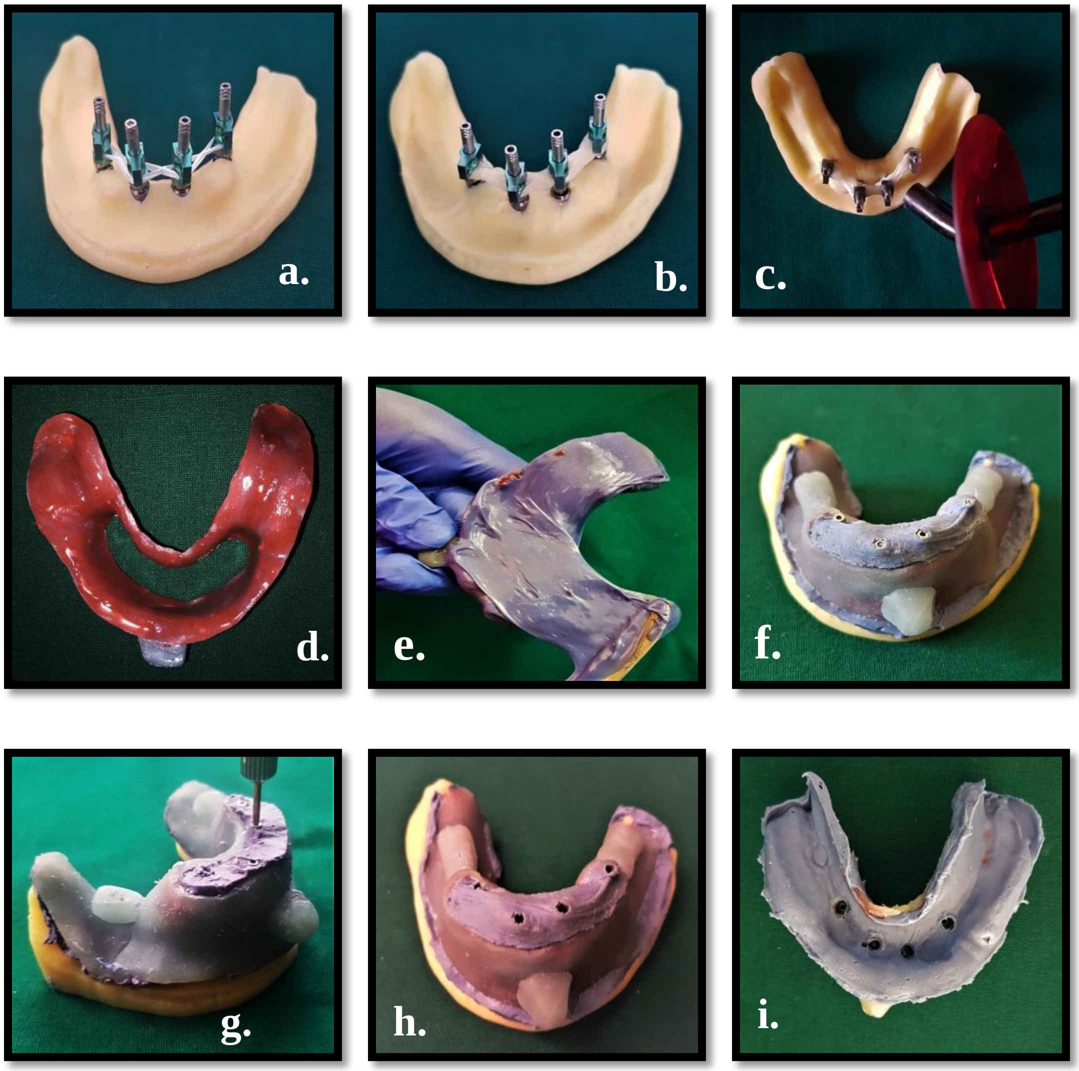


Fig. 37: Group II – Splinting - Floss reinforced with flowable composite

a) Floss tied between impression copings in 8-figure copings **b)** Floss is reinforced with super low flow flowable composite **c)** Flowable composite cured for 10 seconds **d)** Application of polyether adhesive **e)** Loading of tray with Polyether impression material **f)** Completely seated impression with excess removed **g & h)** Unscrewing of long handles **i)** Completed impression showing the intaglio surface

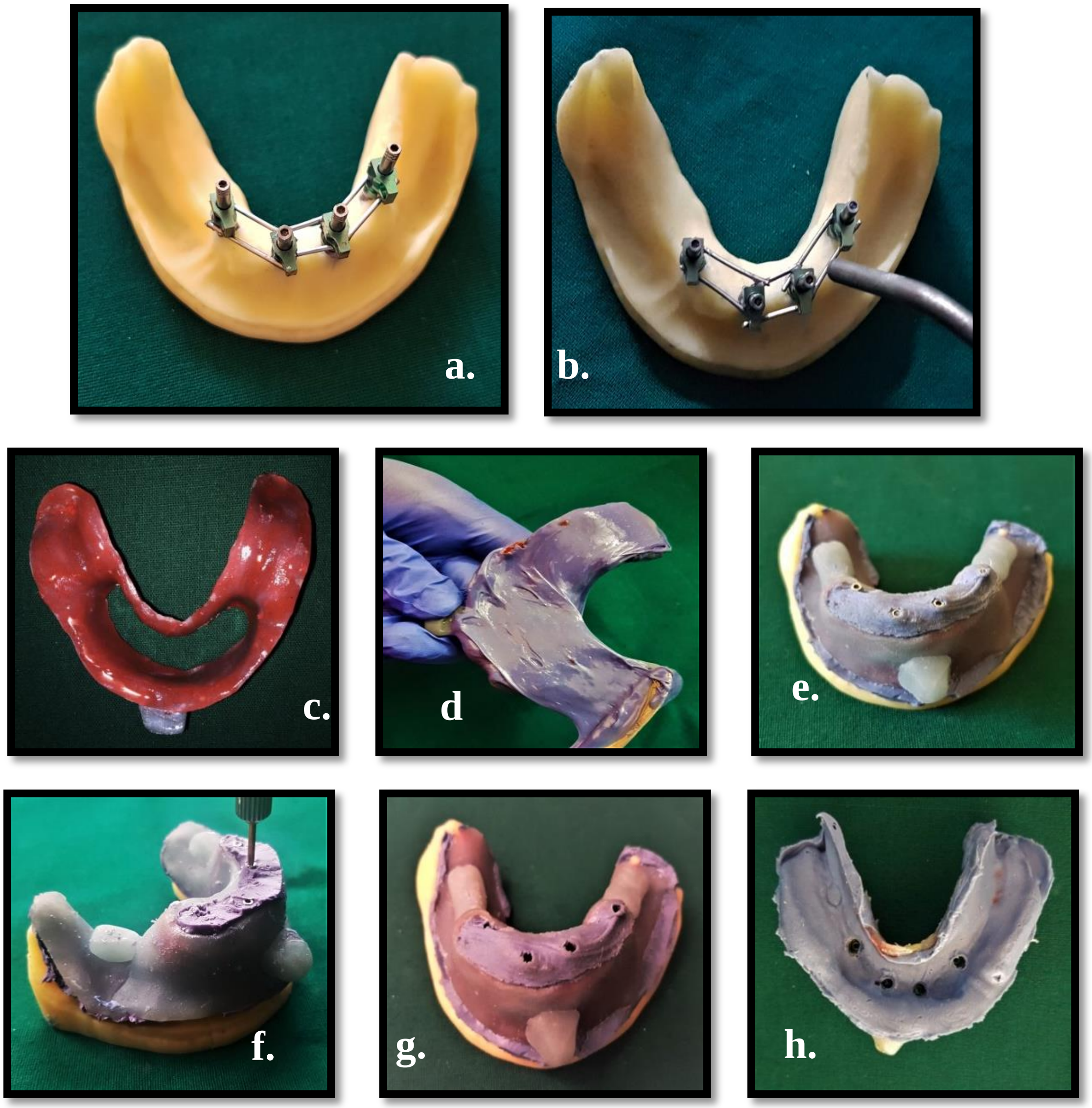


Fig. 38: Group III – Splinting - Orthodontic wire affixed with universal bonding agent

a) Orthodontic wire of 19 gauge is sectioned and placed between impression copings **b)** Application of universal bonding agent and air dried **c)** Application of polyether adhesive **d)** Loading of tray with Polyether impression material **e)** Completely seated impression with excess removed **f & g)** Unscrewing of long handles **h)** Completed impression showing the intaglio surface

IV. OBTAINING MASTER CASTS

Fig. 39: Positioning of laboratory analogs to impression copings

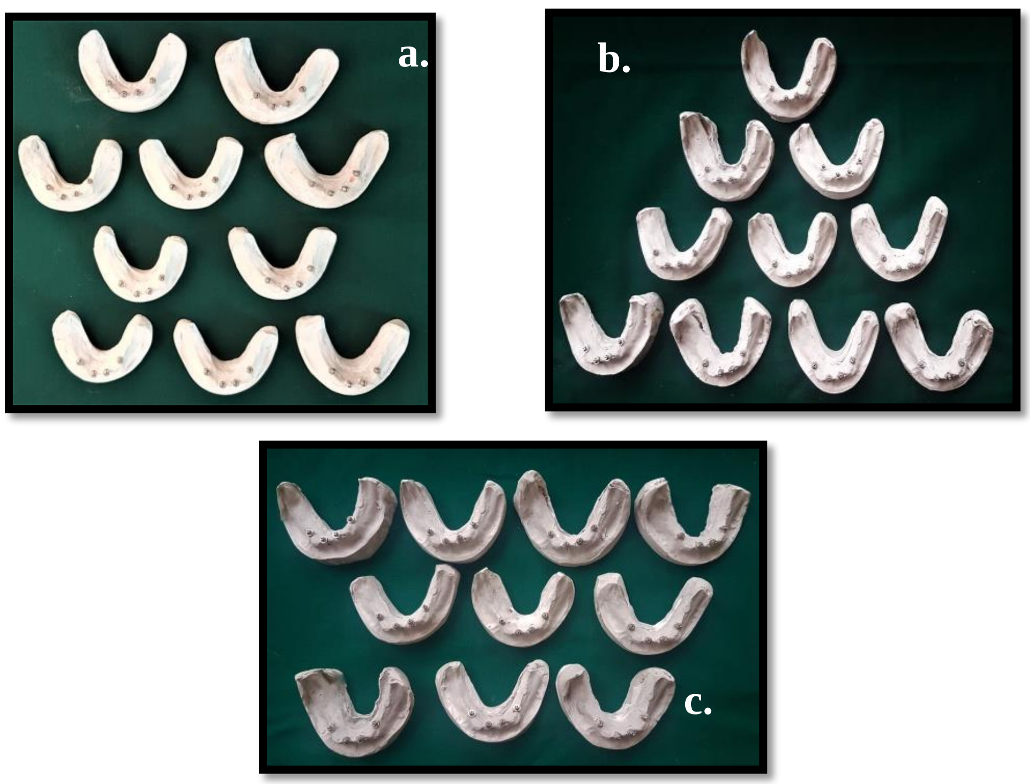


Fig. 40 (a): Group I casts (n=10 per group)

Fig. 40 (b): Group II casts (n=10 per group)

Fig. 40 (c): Group III casts (n=10 per group)

V. EVALUATION OF REFERENCE MODEL AND MASTER CASTS

Fig. 41: Coordinate measuring machine (CMM)

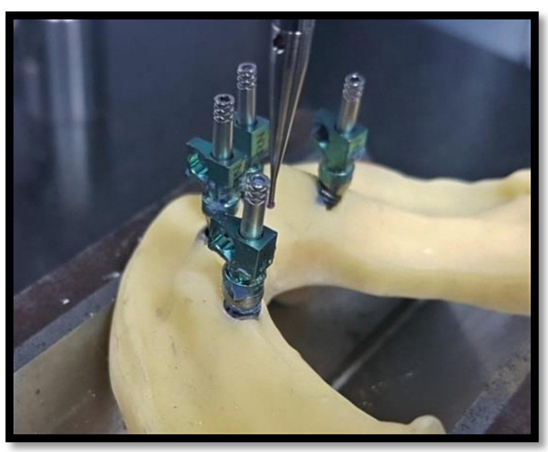


Fig. 42: Measuring the reference model using coordinate measuring machine

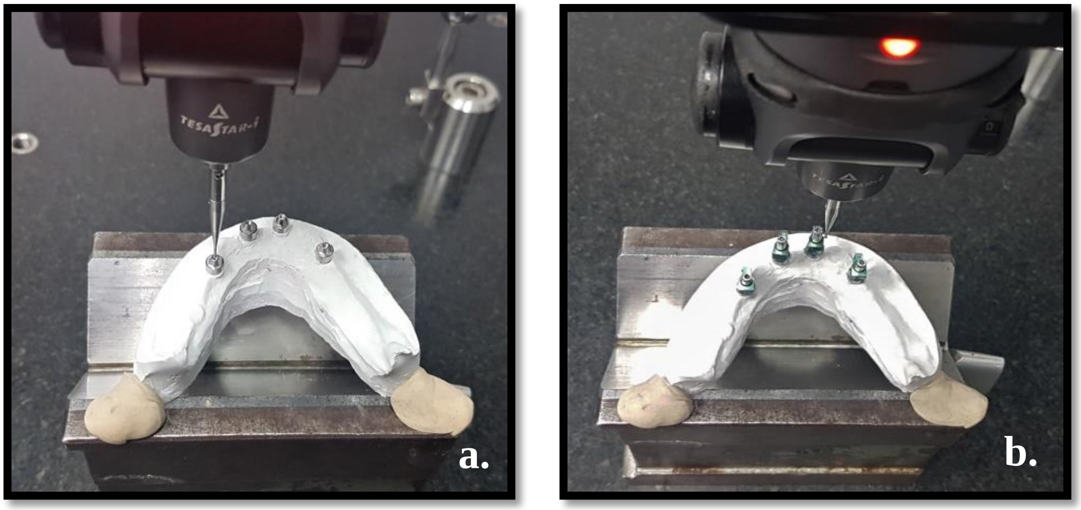


Fig. 43: Measuring the master cast using coordinate measuring machine
a) Measuring the position and platform of the implant analog
b) Measuring the inter implant angulations with impression copings positioned

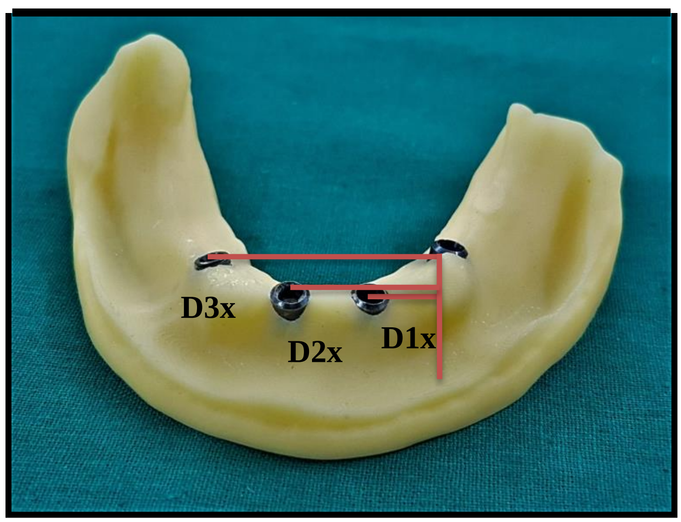


Fig. 44: Inter Implant distances in X-axis

D1x – Distance between the implant analog 1 and 2
D2x – Distance between the implant analog 1 and 3
D3x – Distance between the implant analog 1 and 4

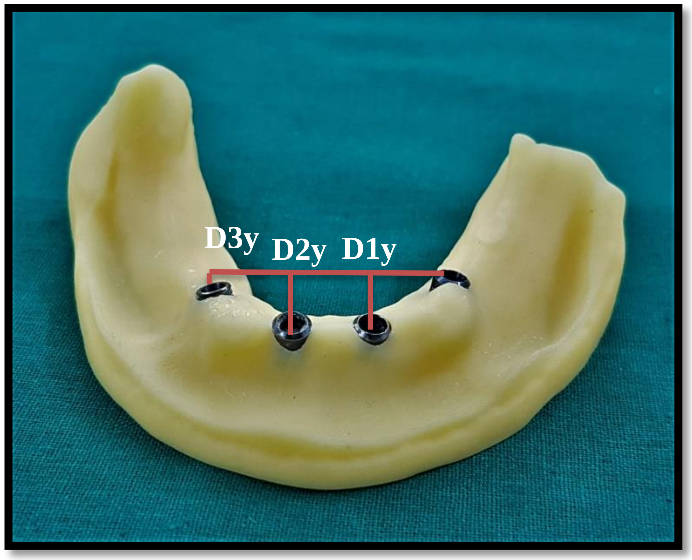


Fig. 45: Inter Implant distances in Y-axis

D1y – Distance between the implant analog 1 and 2

D2y – Distance between the implant analog 1 and 3

D3y – Distance between the implant analog 1 and 4

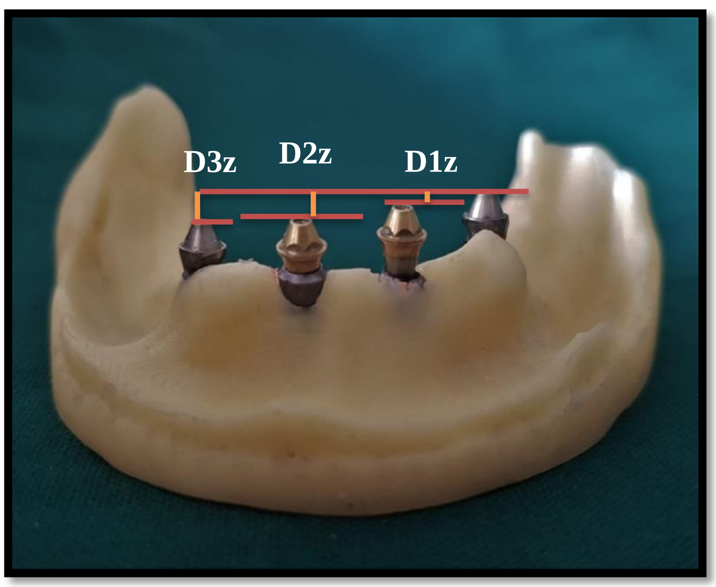


Fig. 46: Inter Implant distances in Z-axis

D1z – Distance between the implant analog 1 and 2

D2z – Distance between the implant analog 1 and 3

D3z – Distance between the implant analog 1 and 4

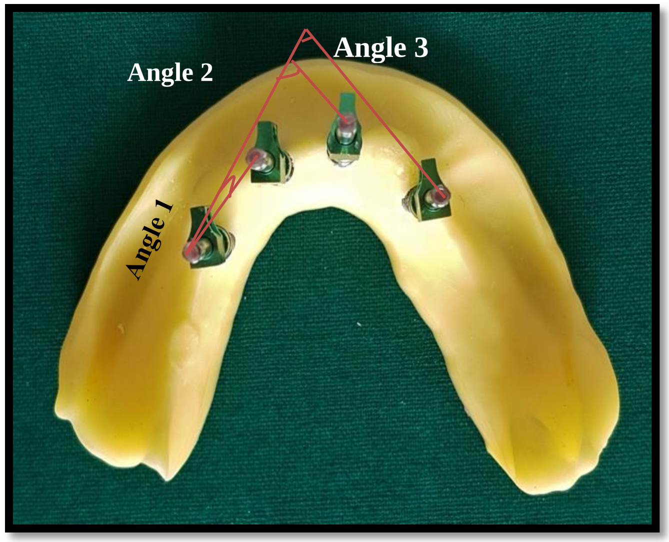


Fig. 47: Inter Implant angulations in Z-axis

Angle 1 – Angle between the implant analog 1 and 2

Angle 2 – Angle between the implant analog 1 and 3

Angle 3 – Angle between the implant analog 1 and 4

Results

RESULTS

The aim of the present *in vitro* study was to compare the inter implant distances in x, y and z axis and the angular relationships between the implant replicas around z axis in *All-on-four* treatment protocol. The four parameters of the test groups were compared with that of the reference model as well as within the test groups and analysed.

Thirty master casts i.e., n=10/group were obtained from the impressions. The study groups were designated as Group I (Floss reinforced with acrylic resin splinted technique), Group II **(**Floss reinforced with flowable composite) and Group III (Orthodontic wire affixed to impression coping with Universal bonding agent).

Five readings were made for the reference model in the x, y, z axes and inter implant angulations and their mean and standard deviation (S.D) values were obtained. Ten master casts were analyzed and their readings were tabulated for each test group. Their mean and standard deviation values were obtained. They were statistically analysed by using one sample test (T-test), one way ANOVA and Post HOC Tukey's test with significance level of 0.05.

TABLE 1: INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS FOR THE REFERENCE MODEL (VALUES IN MM)

Reference model	READINGS					Mean/ S.D
	I	II	III	IV	V	
D1x	8.57	8.46	8.68	8.45	8.5	**8.53/0.354**
D2x	17.25	17.57	18.25	17.77	17.35	**17.64/0.177**
D3x	29.22	29.39	29.2	29	29.65	**29.29/0.258**
D1y	10.5	10.2	11.58	10.85	10.5	**10.7/0.529**
D2y	14.25	13.97	14.145	14	14.5	**14.17/0.47**
D3y	7.03	6.09	6.58	6.09	6.15	**6.39/0.492**
D1z	1.37	1.09	1.25	0.99	1.20	**1.184/0.146**
D2z	1.33	1.01	1.13	1.25	1.35	**1.214/0.14**
D3z	-0.18	-0.25	-0.161	-0.273	-0.175	**-.208/0.050**

Key: Distance in X-axis

D1x denotes the distance between implant replica 1 and 2 in the x-axis

D2x denotes the distance between implant replica 1 and 3 in the x-axis

D3x denotes the distance between implant replica 1 and 4 in the x-axis

Key: Distance in Y-axis

D1y denotes the distance between implant replica 1 and 2 in the y-axis

D2y denotes the distance between implant replica 1 and 3 in the y-axis

D3y denotes the distance between implant replica 1 and 4 in the y-axis

Key: Distance in Z-axis

D1z denotes the distance between implant replica 1 and 2 in the z-axis

D2z denotes the distance between implant replica 1 and 3 in the z-axis

D3z denotes the distance between implant replica 1 and 4 in the z-axis

Inference:

- In the D1x-axis, the reference mean value obtained was **8.53** and standard deviation was **0.354**. In the D2x-axis, the reference mean value obtained was **17.64** and standard deviation was **0.177**. In the D3x-axis, the reference mean value obtained was **29.29** and standard deviation was **0.258**.
- In the D1y-axis, the reference mean value was **10.70** and standard deviation was **0.529**. In the D2y-axis, the reference mean value was **14.17** and standard deviation was **0.47**. In the D3y -axis, the reference mean derived was **6.39** and standard deviation was **0.492**.
- For D1z-axis, the reference mean value obtained was **1.184** and standard deviation was **0.146**. For D2z-axis, the reference mean value obtained was **1.214** and standard deviation was **0.14**. For D3z-axis, the reference mean value obtained was **-0.208** and the standard deviation was **0.050.**

TABLE 2: INTER IMPLANT ANGULATIONS IN Z-AXIS FOR THE REFERENCE MODEL (VALUES IN DEGREES)

Reference model	READINGS					Mean/ S.D
	I	II	III	IV	V	
Angle 1	43.45	44.79	45.23	44.92	43.98	**44.47/0.73**
Angle 2	76.41	77.25	77.57	78.27	76.05	**77.11/0.89**
Angle 3	113.89	114.25	115.35	115.27	114.95	**114.74/0.64**

Key: Angle in Z-axis

Angle 1 denotes the angle between implant number 1 and 2 around z-axis

Angle 2 denotes the angle between implant number 1 and 3 around z-axis

Angle 3 denotes the angle between implant number 1 and 4 around z-axis

Inference: The reference mean value obtained for Angle 1 in z-axis was **44.47** and standard deviation was **0.73.** For Angle 2, the reference mean value was **77.11** and standard deviation was **0.89.** For Angle 3, the reference mean value obtained was **114.74** and the standard deviation was **0.64.**

TABLE 3: INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS FOR MASTER CASTS OF GROUP I (VALUES IN MM)

Group I Readings	D1x	D2x	D3x	D1y	D2y	D3y	D1z	D2z	D3z
I	8.3	17.02	28.98	9.962	13.78	9.45	0.75	0.81	-0.52
II	9.56	18.79	29.93	9.536	12.34	4.49	0.57	1.24	-0.05
III	8.45	17.95	29.14	9.77	12.03	5.94	0.66	2.27	-0.04
IV	7.72	16.80	28.39	10.47	13.78	8.57	0.23	1.21	-0.05
V	5.39	14.27	26.88	11.79	15.83	13.29	0.67	2.39	-0.036
VI	6.77	15.97	28.40	11.33	15.36	10.30	0.5	2.40	-0.03
VII	8.17	17.91	29.29	10.15	12.99	5.66	0.23	1.74	-0.55
VIII	8.37	17.66	28.88	10.03	13.05	6.63	0.86	0.09	-0.01
IX	7.05	13.74	28.42	11.07	13.74	9.85	0.86	1.56	-0.097
X	7.75	17.15	29.07	10.87	12.93	7.19	0.75	1.008	-0.129
Mean	**7.76**	**16.99**	**28.73**	**10.50**	**10.44**	**10.62**	**0.61**	**1.20**	**1.03**
S.D	**1.14**	**1.26**	**0.80**	**0.74**	**0.17**	**0.14**	**0.23**	**0.17**	**0.48**

(Refer Key: Distance in X-axis, Y-axis and Z-axis)

Inference:

- For Group I, the mean value obtained for D1x-axis was **7.76** and standard deviation was **1.14**. For D2x-axis, the mean value obtained was **16.99** and standard deviation was **1.26**. For D3x-axis, the mean value obtained was **28.73** and the standard deviation was **0.80**.
- The mean value for D1y- axis obtained was **10.50** and standard deviation was **0.74**. For D2y-axis, the mean value obtained was **10.44** and standard deviation was **0.17**. For D3y-axis, the mean value obtained was **10.62** and the standard deviation was **0.14.**
- The mean value obtained for D1z-axis was **0.61** and standard deviation was **0.23.** For D2z-axis, the mean value obtained was **1.20** and standard deviation was **0.17.** For D3z- axis, the mean value obtained was **1.03** and the standard deviation was **0.48**.

TABLE 4: INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS FOR MASTER CASTS OF GROUP II (VALUES IN MM)

Group II Reading	D1x	D2x	D3x	D1y	D2y	D3y	D1z	D2z	D3z
I	8.08	16.05	29.05	10.75	13.25	5.89	1.08	1.03	-0.17
II	8.02	17.52	29.02	10.57	13.2	3.19	1.23	1.15	-0.03
III	8.34	16.54	29.19	10.27	14.53	6.17	1.064	1.12	-0.15
IV	8.48	15.36	28.15	10.42	14.57	5.95	1.02	1.44	-0.17
V	8.23	16.70	28.57	10.67	13.59	6.16	1.125	1.25	-0.05
VI	8.032	17.05	28.05	10.3	13.92	6.18	1.274	1.165	-0.13
VII	8.854	16.87	29.08	10.35	13.62	6.58	1.237	1.42	-0.08
VIII	8.33	17.18	29.15	10.23	14.27	5.95	1.57	1.22	-0.029
IX	8.43	16.59	29.05	10.48	13.25	6.32	1.3	1.49	-0.02
X	9.102	17.26	29.02	10.38	13.87	5.09	1.14	1.52	-0.08
Mean	**8.39**	**16.71**	**28.83**	**10.44**	**13.81**	**5.75**	**1.20**	**1.28**	**-0.09**
S.D	**0.35**	**0.63**	**0.42**	**0.17**	**0.52**	**0.98**	**0.16**	**0.17**	**0.06**

(Refer Key: Distance in X-axis, Y-axis and Z-axis)

Inference:

- For Group II, the mean value obtained for D1x-axis was **8.39** and standard deviation was **0.35**. For D2x-axis, the mean value obtained was **16.71** and standard deviation was **0.63**. For D3x-axis, the mean value obtained was **28.83** and standard deviation was **0.42**.
- The mean value for D1y-axis obtained was **10.44** and standard deviation was **0.17**. For D2y-axis, the mean value obtained was **13.81** and standard deviation was **0.52**. For D3y-axis, the mean value obtained was 5**.75** and the standard deviation was **0.98**.
- The mean value obtained for D1z-axis was **1.20** and standard deviation was **0.16.** For D2z-axis, the mean value obtained was **1.28** and standard deviation was **0.17.** For D3z- axis, the mean value obtained was **-0.09** and the standard deviation was **0.06.**

TABLE 5: INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS FOR MASTER CASTS OF GROUP III (VALUES IN MM)

Group III / Reading	D1x	D2x	D3x	D1y	D2y	D3y	D1z	D2z	D3z
I	8.63	17.85	29.24	10.72	13.83	6.22	1.43	1.40	-0.07
II	8.10	18.23	29.03	10.56	13.72	6.44	0.18	1.08	-0.44
III	8.27	17.12	29.27	10.7	14.30	6.68	1.34	1.26	-0.06
IV	8.37	17.62	29.75	10.42	13.92	6.39	0.53	1.48	-0.05
V	8.52	17.77	29.28	10.87	13.66	6.55	0.48	1.73	-0.02
VI	8.92	17.83	29.07	10.64	13.08	6.21	1.63	1.018	-1.02
VII	8.10	17.31	30.01	10.36	14.72	6.18	1.51	0.49	-0.03
VIII	8.46	17.75	29.04	10.65	14.26	6.85	1.20	0.52	-0.02
IX	8.43	17.67	29.45	10.62	14.30	5.97	1.63	0.24	-0.09
X	8.5	17.45	29.05	10.64	13.56	6.18	1.6	0.99	-0.04
Mean	**8.43**	**17.66**	**29.32**	**10.62**	**13.94**	**6.37**	**1.16**	**1.03**	**-0.19**
S.D	**0.24**	**0.31**	**0.33**	**0.14**	**0.47**	**0.27**	**0.54**	**0.48**	**0.32**

(Refer Key: Distance in X-axis, Y-axis and Z-axis)

Inference:

- For Group III, the mean value obtained for D1x-axis was **8.43** and standard deviation was **0.24**. For D2x-axis, the mean value obtained was **17.66** and standard deviation was **0.31**. For D3x-axis, the mean value obtained was **29.32** and the standard deviation was **0.33**.
- The mean value obtained for D1y-axis was **10.62** and standard deviation was **0.14**. For D2y-axis, the mean value obtained was **13.94** and standard deviation was **0.47.** For D3y- axis, the mean value obtained was **6.37** and the standard deviation was **0.27.**
- The mean value obtained for D1z-axis **1.16** and standard deviation was **0.54**. For D2z-axis, the mean value obtained was **1.03** and standard deviation was **0.48**. For D3z- axis, the mean value obtained was **-0.19** and the standard deviation were **0.32.**

TABLE 6: INTER IMPLANT ANGULATIONS IN Z- AXIS FOR MASTER CASTS OF GROUP I, GROUP II AND GROUP III (VALUES IN DEGREES)

	Group I			Group II			Group III		
	Angle 1	**Angle 2**	**Angle 3**	**Angle 1**	**Angle 2**	**Angle 3**	**Angle 1**	**Angle 2**	**Angle 3**
I	38.42	66	99.35	43.57	78.46	127.52	43.92	76.95	114.2
II	37.77	67.45	93.29	45.08	79.87	129.75	44.75	76.99	114.92
III	37.43	64.97	103.21	44.02	74.71	128.88	44.23	76.23	114.56
IV	39.82	67.51	104.77	43	78.91	127.9	44.15	76.75	114.97
V	39.47	70.98	115.45	43.6	75.79	128.65	44	76.97	113.97
VI	41.9	70.58	111.78	45.24	76.86	126.5	44.46	76.74	114.03
VII	33.73	58.4	102.39	45.16	76.32	121.07	45.05	76.52	114.85
VIII	40.06	69.06	109.52	43.05	73.76	120.52	44.43	78.91	114.2
IX	41.96	71.61	110.55	43.44	76.2	128.77	43.97	76.99	115.02
X	46.18	74.75	126.88	42.95	77.84	124.07	43.75	76.56	114.98
Mean	**39.67**	**68.13**	**107.71**	**43.91**	**76.85**	**114.27**	**44.3**	**76.96**	**114.57**
S.D	**3.30**	**4.48**	**9.37**	**0.92**	**1.81**	**0.62**	**0.40**	**0.72**	**0.42**

(Refer Key: Angle in Z-axis)

Inference:

- For Group I, the mean value obtained for Angle 1 was **39.67** and standard deviation was **3.30.** For Angle 2, the mean value obtained was **68.13** and standard deviation was **4.48**. For Angle 3, the mean value obtained was **107.71** and the standard deviation was **9.37.**
- For Group II, the mean value obtained for Angle 1 was **43.91** and standard deviation was **0.92.** For Angle 2, the mean value obtained was **76.85** and standard deviation was **1.81.** For Angle 3, the mean value obtained was **114.27** and the standard deviation was **0.62**.
- For Group III, the mean value obtained for Angle 1 was **44.3** and standard deviation was **0.4.** For Angle 2, the mean value obtained was **76.96** and standard deviation was **0.72.** For Angle 3, the mean value obtained was **114.57** and the standard deviation was **0.42.**

TABLE 7: COMPARATIVE EVALUATION OF INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS BETWEEN REFERENCE MODEL AND GROUP I, GROUP II & GROUP III BY ONE SAMPLE TEST (T-TEST)

Groups		D1x	D2x	D3x	D1y	D2y	D3y	D1z	D2z	D3z
Reference	Mean	8.53	17.64	29.29	10.7	14.17	6.39	1.184	1.214	-.208
	` S.D	0.354	0.177	0.258	0.529	0.47	0.492	0.146	0.14	0.050
Group I	Mean	7.76	16.99	28.73	10.50	13.58	8.14	0.61	1.48	-0.15
	S.D	1.14	1.26	0.80	0.74	1.22	2.66	0.23	0.75	0.20
	P-value	0.059	0.139	0.054	0.41	0.162	0.067	0.000*	0.301	0.46
Group II	Mean	8.39	17.57	29.21	10.61	13.81	5.75	1.20	1.28	-0.2
	S.D	0.35	0.29	0.28	0.21	0.52	0.98	0.16	0.17	0.08
	P-value	0.241	0.44	0.39	0.21	0.054	0.069	0.696	0.252	0.89
Group III	Mean	8.43	17.66	29.32	10.62	13.94	6.37	1.16	1.03	-0.19
	S.D	0.24	0.31	0.33	0.14	0.47	0.27	0.54	0.48	0.32
	P-value	0.234	0.813	0.762	0.099	0.151	0.821	0.87	0.24	0.83

Inference: One sample T- test analysis revealed statistically significant difference in the distance between the implant analog 1 and implant analog 4 in z-axis from the reference model. **(0.000*)**

TABLE 8: COMPARISON OF INTER IMPLANT ANGULATIONS IN Z-AXIS FOR GROUPS I, II AND III BY ONE SAMPLE TEST (T-TEST)

Groups		Angle 1	Angle 2	Angle 3
Reference	Mean	44.47	77.11	114.7
	S.D	0.73	0.89	0.64
Group I	Mean	39.67	68.13	107.72
	S.D	3.30	4.48	9.37
	P-value	0.000*	0.000*	0.04*
Group II	Mean	43.9	76.8	114.6
	S.D	0.92	1.81	0.5
	P-value	0.087	0.67	0.29
Group III	Mean	44.27	77	114.6
	S.D	0.40	0.73	0.41
	P-value	0.154	0.53	0.33

Inference: One sample T- test revealed statistically significant results in the inter implant angulation between the four implant analogs in Group I from the reference model **(0.000*) (0.04*)**

TABLE 9: COMPARATIVE EVALUATION OF INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS FOR TEST GROUPS I, II AND III BY ONE WAY ANALYSIS OF VARIANCE (ANOVA)

	P- Value
D1x	**0.071**
D2x	**0.13**
D3x	**0.046***
D1y	**0.797**
D2y	**0.620**
D3y	**0.009***
D1z	**0.001***
D2z	**0.177**
D3z	**0.89**
Angle 1	**0.000***
Angle 2	**0.000***
Angle 3	**0.011***

Inference: The inter implant distances in x-axis, y-axis and z-axis for test Groups I, II and III were compared and evaluated between test groups by One Way Analysis of Variance (ANOVA), the findings were found to be statistically significant in relation to D3x **(0.046*)**, D3y **(0.009*)**, D1z **(0.001*)**, Angles 1 **(0.000*)**, Angle 2 **(0.000*)** and Angle 3 **(0.011*)**.

TABLE 10: COMPARISON OF INTER IMPLANT DISTANCES IN X-AXIS BETWEEN GROUPS I, II AND III BY POST-HOC TUKEY'S HSD TEST (VALUES IN MM)

	Groups	D1X			D2X			D3X		
		Mean Difference	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**
Group I	` **Group II**	-0.63	0.31	**0.126**	-0.57	0.34	**0.23**	-0.45	0.235	**0.15**
	Group III	-0.68	0.31	**0.097**	-0.67	0.34	**0.14**	-0.59	0.235	**0.046***
Group II	**Group I**	0.63	0.31	**0.126**	0.57	0.34	**0.23**	0.45	0.235	**0.15**
	Group III	-0.04	0.31	**0.990**	-0.097	0.34	**0.96**	-0.14	0.235	**0.82**
Group III	**Group I**	0.68	0.31	**0.097**	0.67	0.34	**0.14**	0.59	0.235	**0.046***
	Group II	0.04	0.31	**0.990**	0.097	0.34	**0.96**	0.14	0.235	**0.82**

Inference: Multiple comparisons using Post-hoc Tukey's HSD analysis showed statistically significant results between group I and III in D3x axis. ($p<0.05$)

TABLE 11: COMPARISON OF INTER IMPLANT DISTANCES IN Y-AXIS BETWEEN GROUPS I, II AND III BY POST-HOC TUKEY'S HSD TEST (VALUES IN MM)

	Groups	D1Y			D2Y			D3Y		
		Mean Difference	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**
Group I	**Group II**	-0.12	0.20	**0.83**	-0.22	0.36	**0.81**	2.39	0.73	**0.008***
	Group III	-0.12	0.20	**0.83**	-0.35	0.36	**0.60**	1.77	0.73	**0.058**
Group II	**Group I**	0.12	0.20	**0.83**	0.22	0.36	**0.81**	-2.39	0.73	**0.008***
	Group III	-0.00	0.20	**1.00**	-0.13	0.36	**0.93**	-0.62	0.73	**0.679**
Group III	**Group I**	0.12	0.20	**0.83**	0.35	0.36	**0.60**	-1.77	0.73	**0.058**
	Group II	0.00	0.20	**1.00**	0.13	0.36	**0.93**	0.62	0.73	**0.679**

Inference: Multiple comparisons using Post-hoc Tukey's HSD analysis showed statistically significant results between group I and II in D3y axis.

TABLE 12: COMPARISON OF INTER IMPLANT DISTANCES IN Z-AXIS BETWEEN GROUPS I, II AND III BY POST-HOC TUKEY'S HSD TEST (VALUES IN MM)

	Groups	D1Z			D2Z			D3Z		
		Mean Difference	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**
Group I	**Group II**	-0.59	0.16	**0.002***	0.19	0.23	**0.689**	-0.46	0.100	**0.88**
	Group III	-0.55	0.16	**0.005***	0.45	0.23	**0.153**	0.03	0.100	**0.94**
Group II	**Group I**	0.59	0.16	**0.002***	-0.19	0.23	**0.689**	0.46	0.100	**0.88**
	Group III	0.05	0.16	**0.948**	0.25	0.23	**0.529**	-0.01	0.100	**0.991**
Group III	**Group I**	0.55	0.16	**0.005***	-0.45	0.23	**0.153**	-0.03	0.100	**0.94**
	Group II	-0.05	0.16	**0.948**	-0.25	0.23	**0.529**	-0.01	0.100	**0.991**

Inference: Multiple comparisons using Post-hoc Tukey's HSD analysis showed statistically significant results between Group I and III & Group I and II in D1z axis.

TABLE 13: COMPARISON OF INTER IMPLANT ANGULATIONS IN Z-AXIS BETWEEN GROUPS I, II AND III BY POST-HOC TUKEY'S HSD TEST (VALUES IN DEGREES)

	Groups	Angle 1			Angle 2			Angle 3		
		Mean Difference	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**	**Mean Difference**	**Standard Error**	**P-value**
Group I	` **Group II**	-4.24	0.90	**0.000***	-8.7	1.26	**0.000***	-6.84	2.42	**0.023***
	Group III	-4.46	0.90	**0.000***	-8.8	1.26	**0.000***	-6.88	2.42	**0.022***
Group II	**Group I**	4.24	0.90	**0.000***	8.7	1.26	**0.000***	6.84	2.42	**0.023***
	Group III	-0.22	0.90	**1.00**	-0.10	1.26	**0.99**	-0.04	2.42	**1.000**
Group III	**Group I**	4.46	0.90	**0.000***	8.8	1.26	**0.000***	6.88	2.42	**0.022***
	Group II	0.22	0.90	**1.00**	0.10	1.26	**0.99**	0.04	2.42	**1.000**

Inference: Multiple comparisons using Post-hoc Tukey's HSD analysis showed statistically significant results between Group I and III & Group I and II in Angle 1, Angle 2 and Angle 3. ($p<0.05$)

TABLE 14: DIFFERENCES IN INTER IMPLANT DISTANCES IN X-AXIS, Y-AXIS AND Z-AXIS [VALUES IN MICRONS (µM)]

Group	**I**	**II**	**III**
Δ D1 x	-770	-150	-100
Δ D2 x	-650	-70	20
Δ D3 x	-560	-80	30
Δ D1 y	-200	-90	-80
Δ D2 y	-590	-360	-230
Δ D3 y	1750	-640	-20
Δ D1 z	-574	16	-24
Δ D2 z	266	66	-184
Δ D3 z	58	8	18

Key analysis:
Δ D1 x= D1 x of test group – **D1 x** of reference model
Δ D2 x = D2 x of test group- **D2 x** of reference model
Δ D3 x= D3 x of test group – **D3 x** of reference model

Δ D1 y= D1 y of test group – **D1 y** of reference model

Δ D2 y= D2 y of test group- **D2 y** of reference model

Δ D3 y = D3 y of test group – **D3 y** of reference model

Δ D1 z = D1 z of test group – **D1 z** of reference model

Δ D2 z= D2 z of test group- **D2 z** of reference model

Δ D3z = D3 z of test group – **D3z** of reference model

Inference: The differences in inter implant distances in x-axis was found to be in range of **-560μm to -770μm** for Group I, **-150μm to -80 μm** for Group II and **30μm to -100μm** for Group III.

The differences in inter implant distances in y-axis was found to be in range of **1750μm to -200μm** for Group I, **-640μm to -90 μm** for Group II and **-20μm to -80μm** for Group III.

The differences in inter implant distances in z-axis was found to be in range of **-574μm to 58μm** for Group I, **66μm to 8 μm** for Group II and **18μm to -24μm** for Group III.

TABLE 15: DIFFERENCES IN INTER IMPLANT ANGULATIONS IN Z-AXIS [VALUES IN DEGREES]

Group	I	II	III
Δ Angle 1	-4.8	-0.57	0.2
Δ Angle 2	-8.98	-0.31	-0.11
Δ Angle 3	-6.98	-0.1	-0.1

Key Analysis:

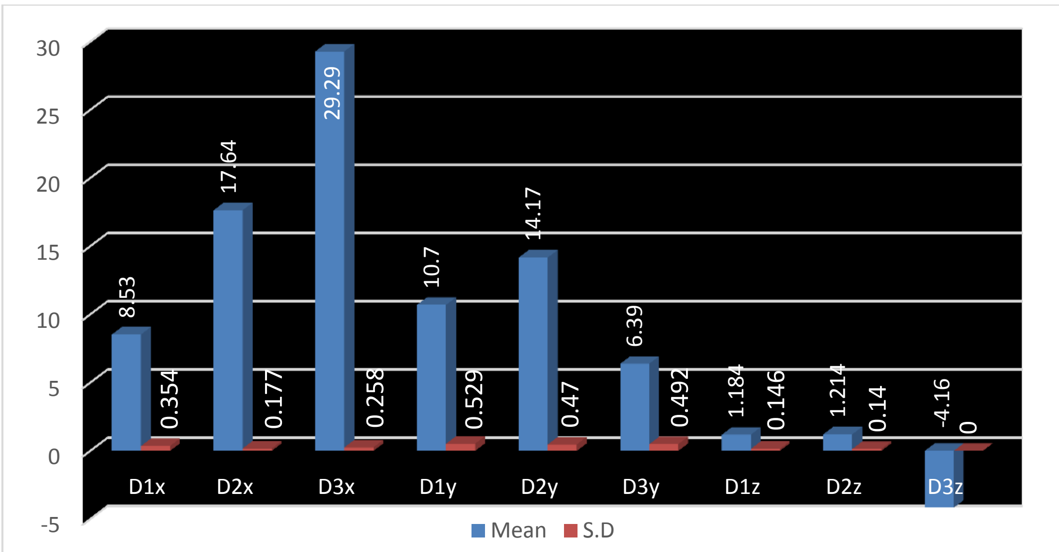
Δ Angle 1 = Angle 1 of test group – Angle 1 of reference model
Δ Angle 2 = Angle 2 of test group- Angle 2 of reference model
Δ Angle 3 = Angle 3 of test group – Angle 3 of reference model

Inference: The differences in inter implant angulation in z-axis was found to be in range of **-8.98 degree to -4.8 degree** for Group I, **-0.1 degree to -0.57 degree** for Group II and **-0.1 to 0.2 degree** for Group III.

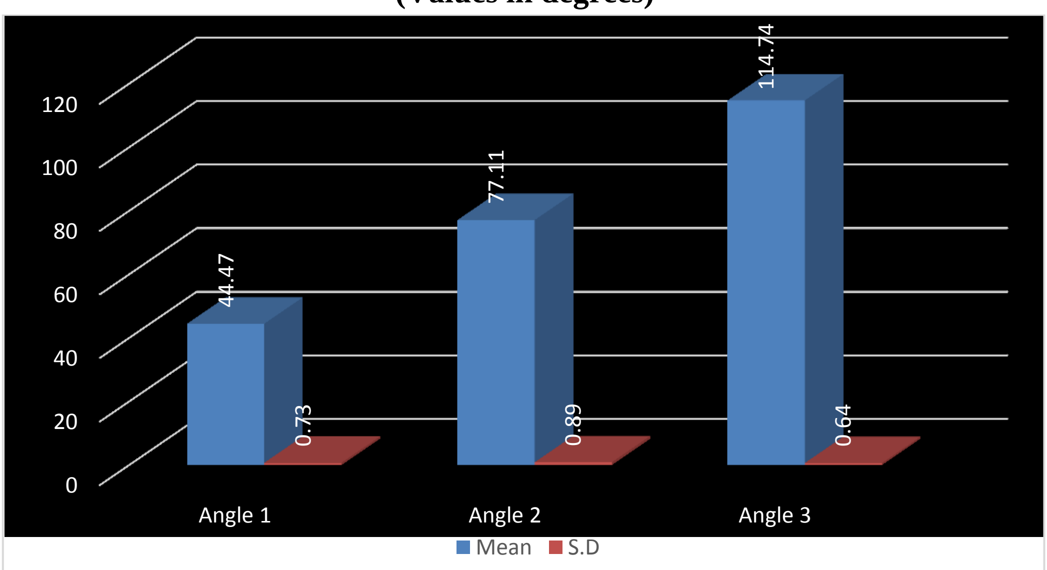
ANNEXURE - III

BAR GRAPHS FOR INTER IMPLANT DISTANCES IN X, Y, Z AXES AND INTER IMPLANT ANGULATION IN Z-AXIS

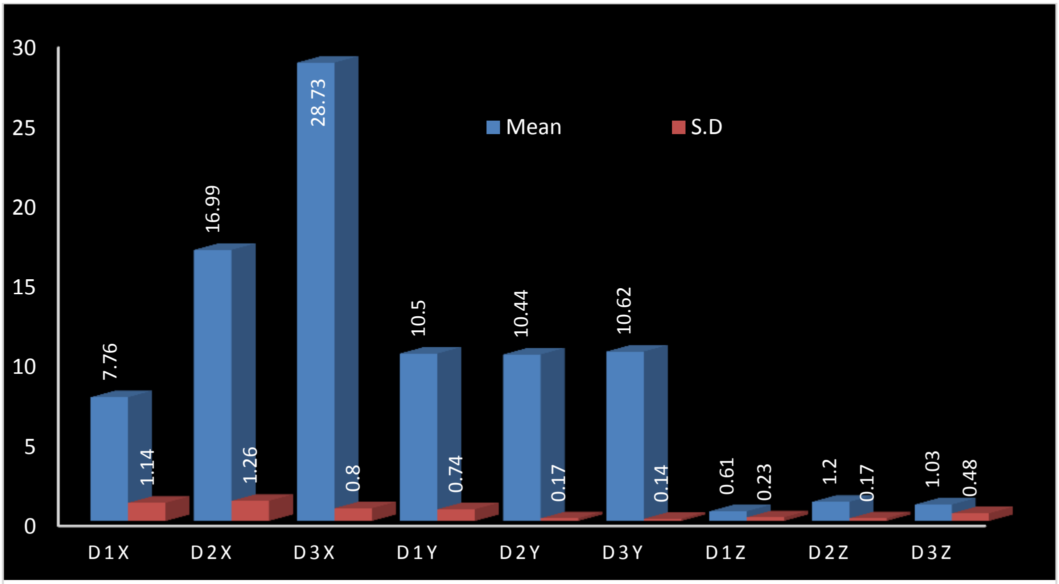
Graph 1: Inter implant distances in x-axis, y-axis and z-axis for the reference model (Values in mm)



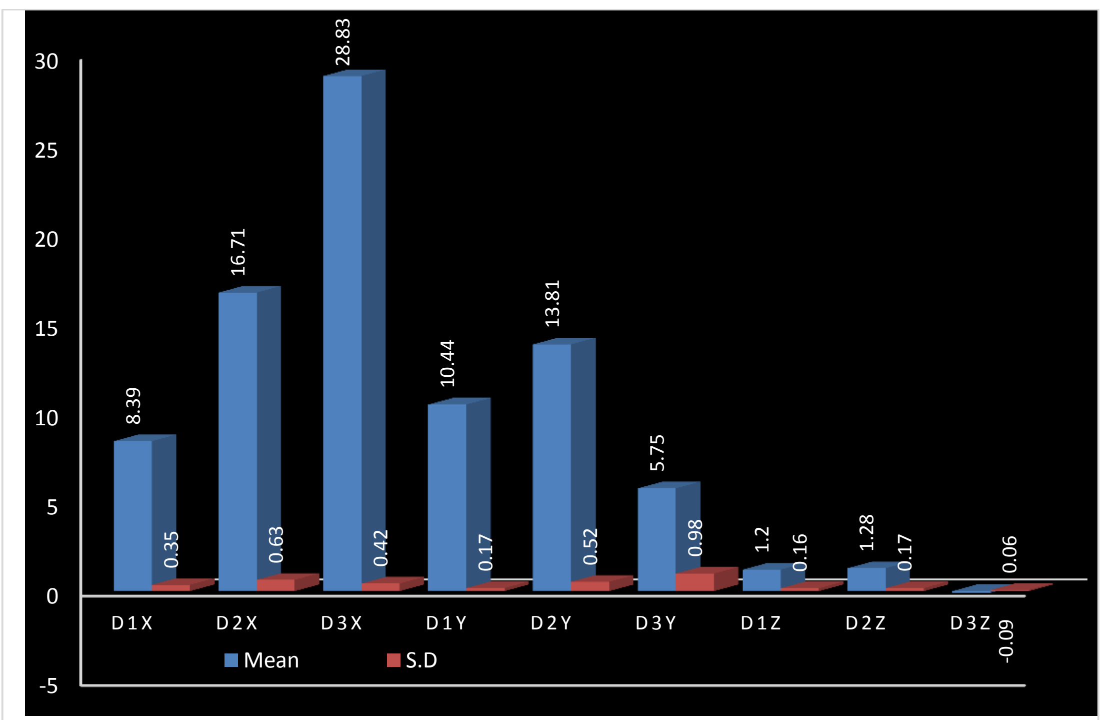
Graph 2: Inter implant angulations in z-axis for the reference model (Values in degrees)



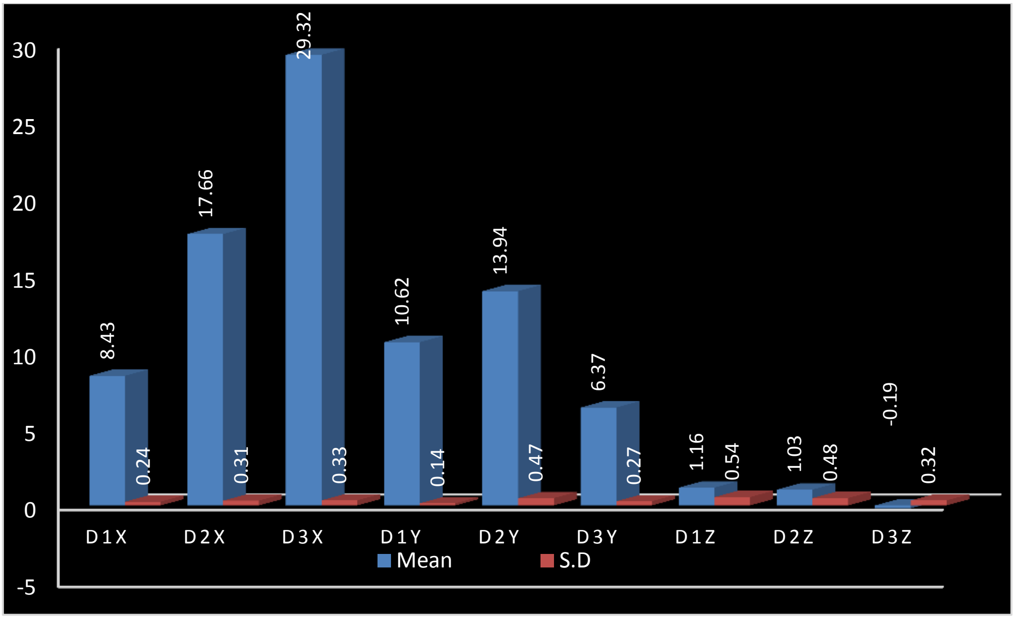
Graph 3: Inter implant distances in x-axis, y-axis and z-axis for master casts of Group I (Values in mm)



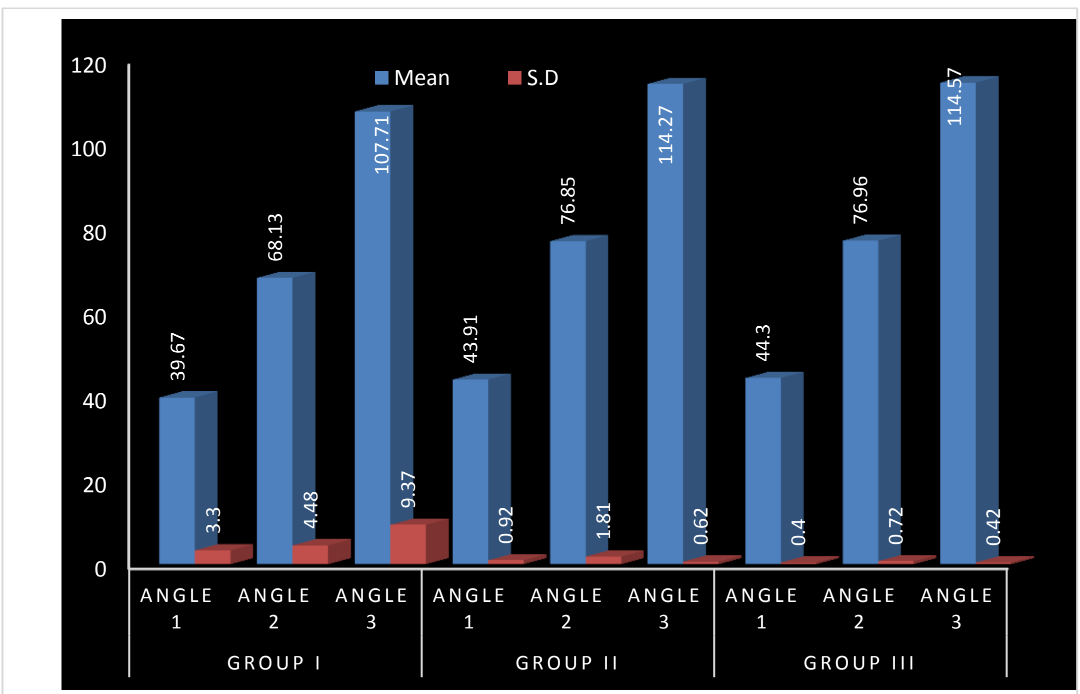
Graph 4: Inter implant distances in x-axis, y-axis and z-axis for master casts of Group II (Values in mm)



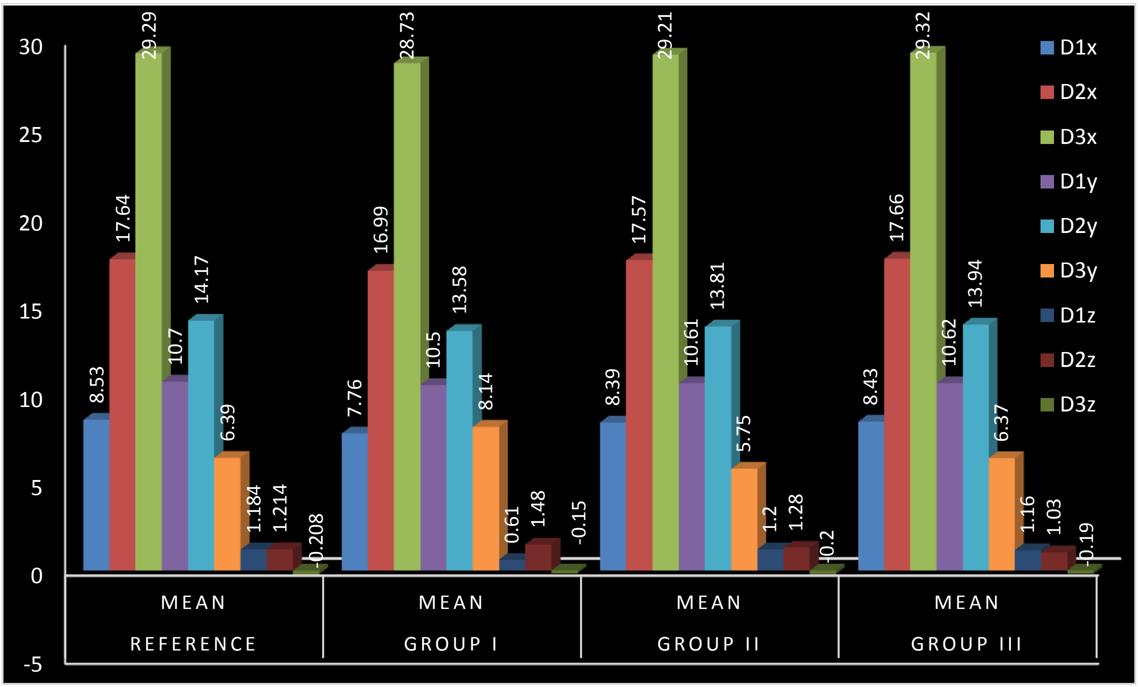
Graph 5: Inter implant distances in x-axis, y-axis and z-axis for master casts of Group III (Values in mm)



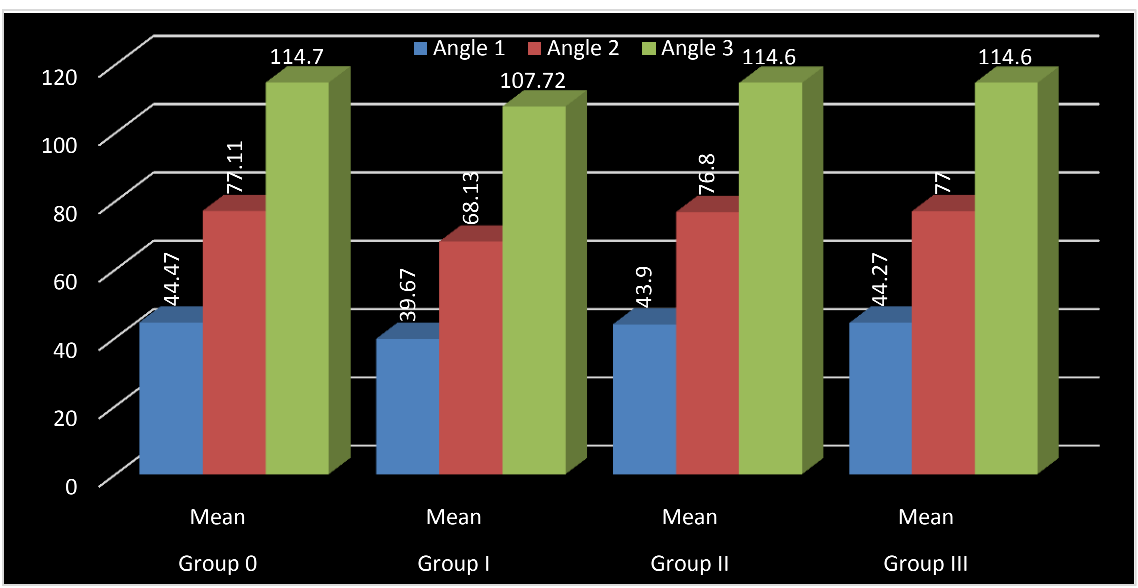
Graph 6: Inter implant angulations in z-axis for master casts of Group I, II and III (Values in degrees)



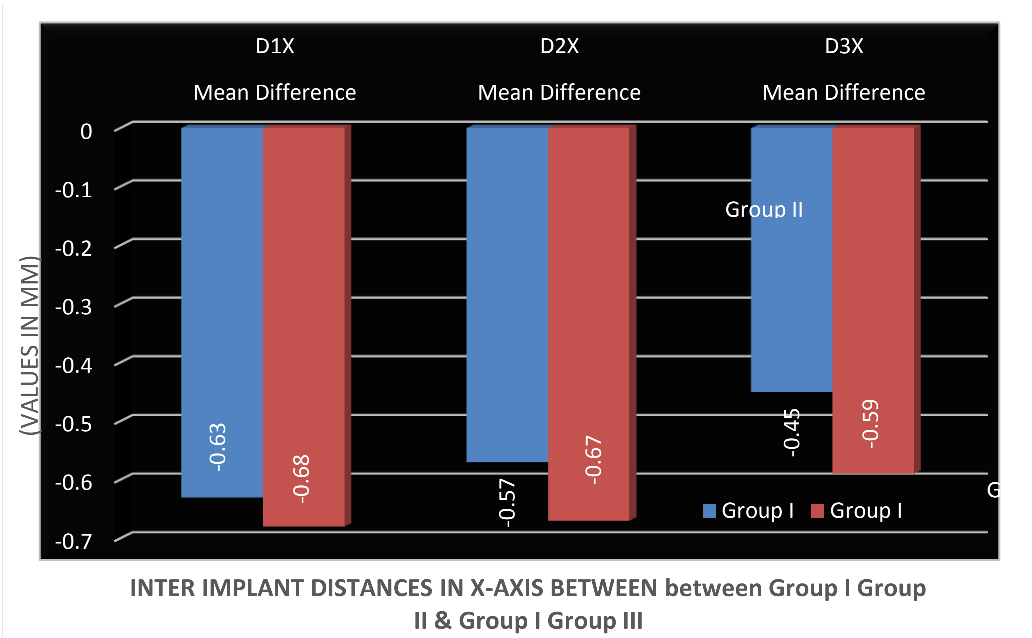
Graph 7: Comparative evaluation of inter implant distances in x-axis, y-axis and z-axis between reference model and Group I, Group II & Group III by one Sample Test (T-Test)



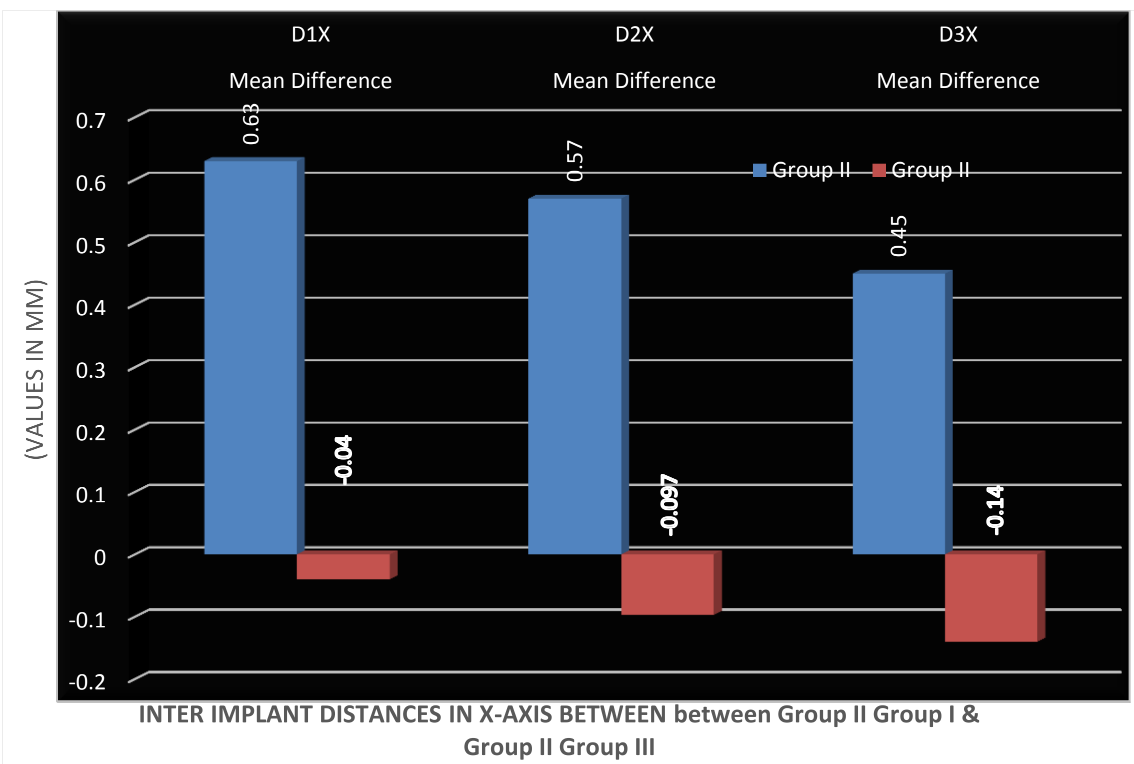
Graph 8: Comparison of inter implant angulations in z-axis for Groups I, II and III by One sample test (T-test)



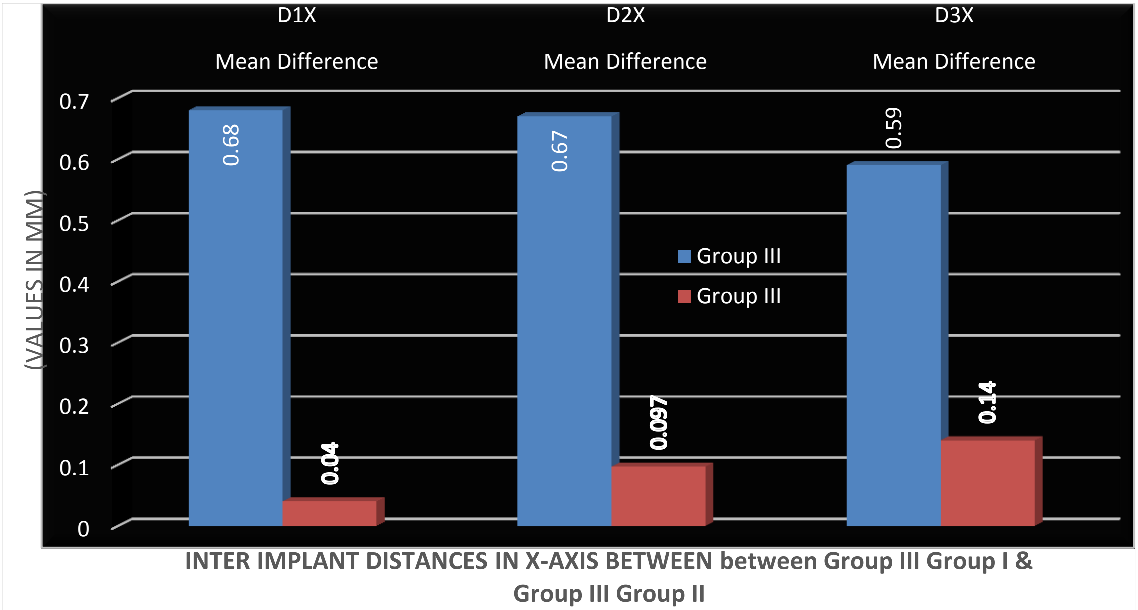
Graph 9a: Comparative evaluation of inter implant distances in x-axis between Group I and Group II & Group I and Group III.



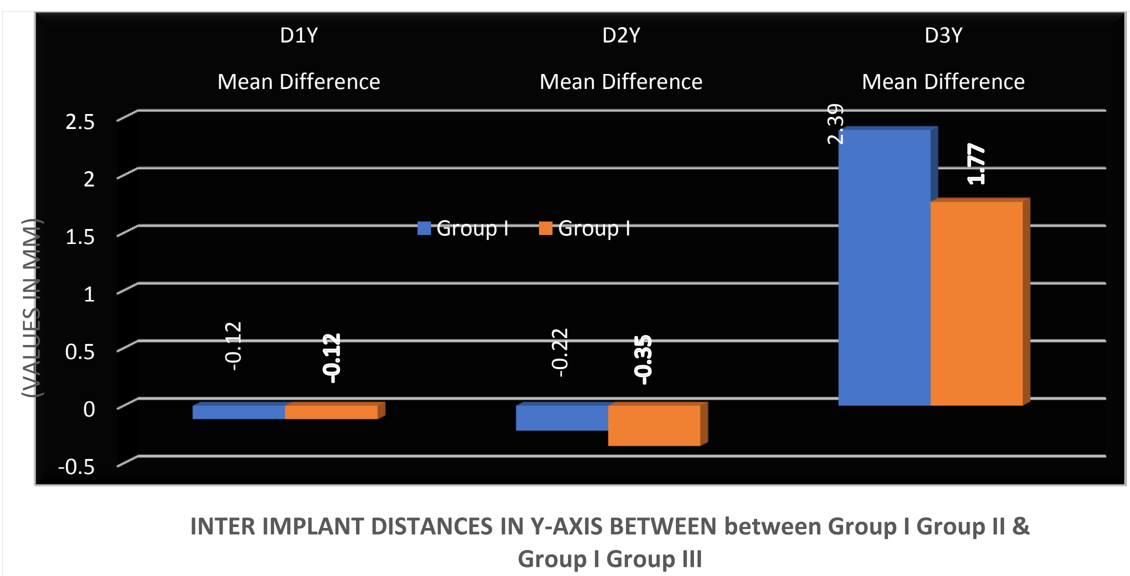
Graph 9b: Comparative evaluation of inter implant distances in x-axis between Group II and Group I & Group II and Group III



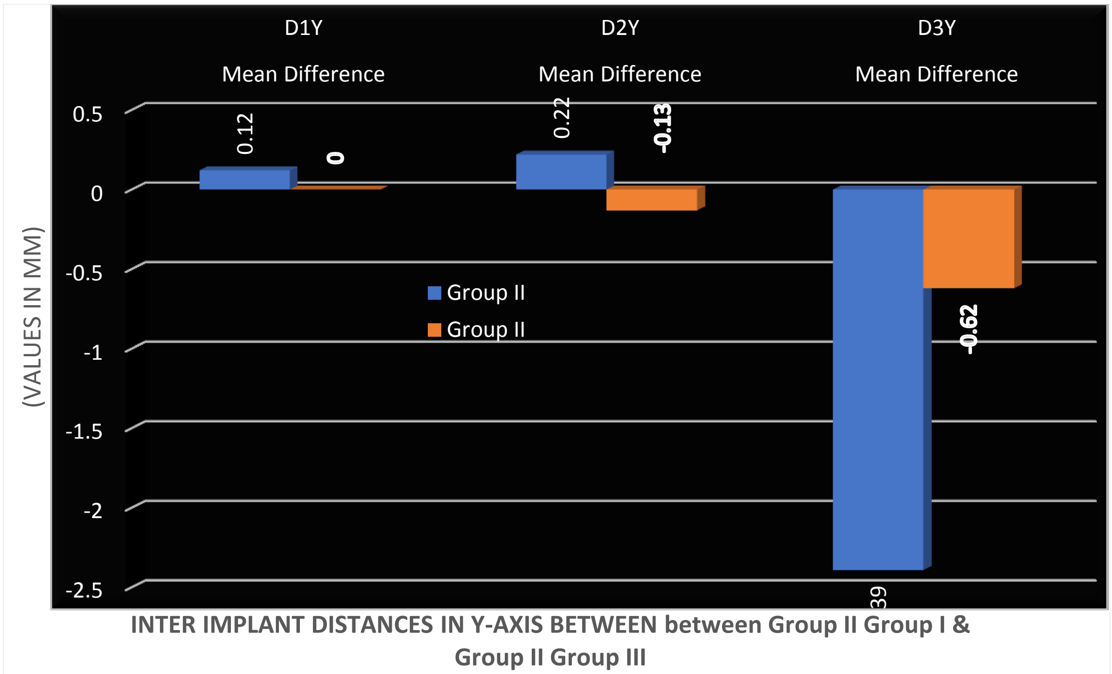
Graph 9c: Comparative evaluation of inter implant distances in x-axis between Group III and Group I & Group III and Group II



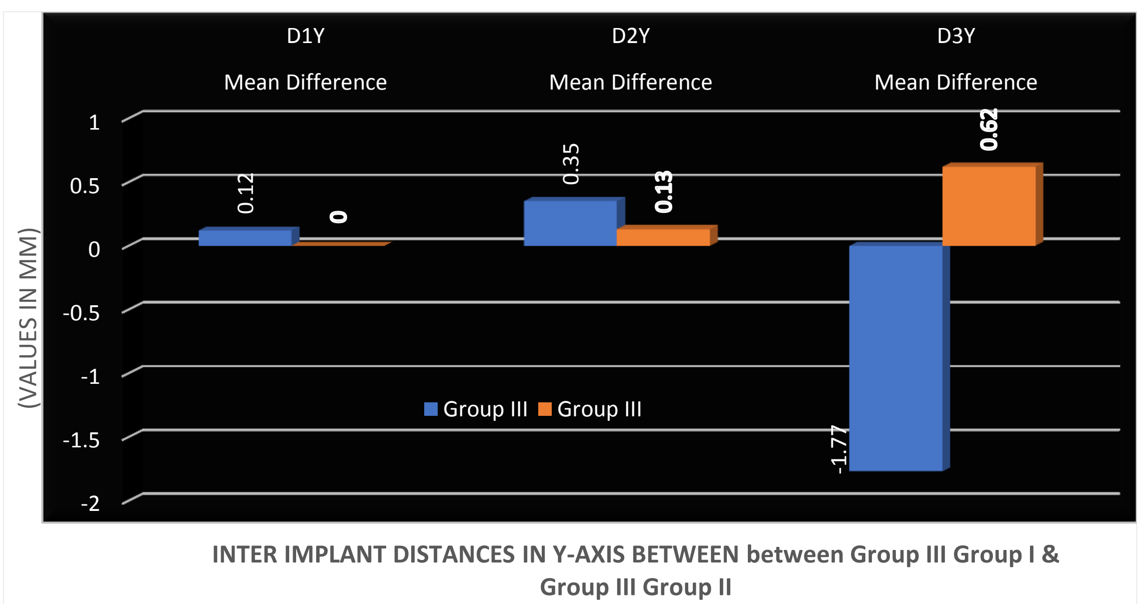
Graph 10a: Comparative evaluation of inter implant distances in Y-axis between Group I and Group II & Group I and Group III.



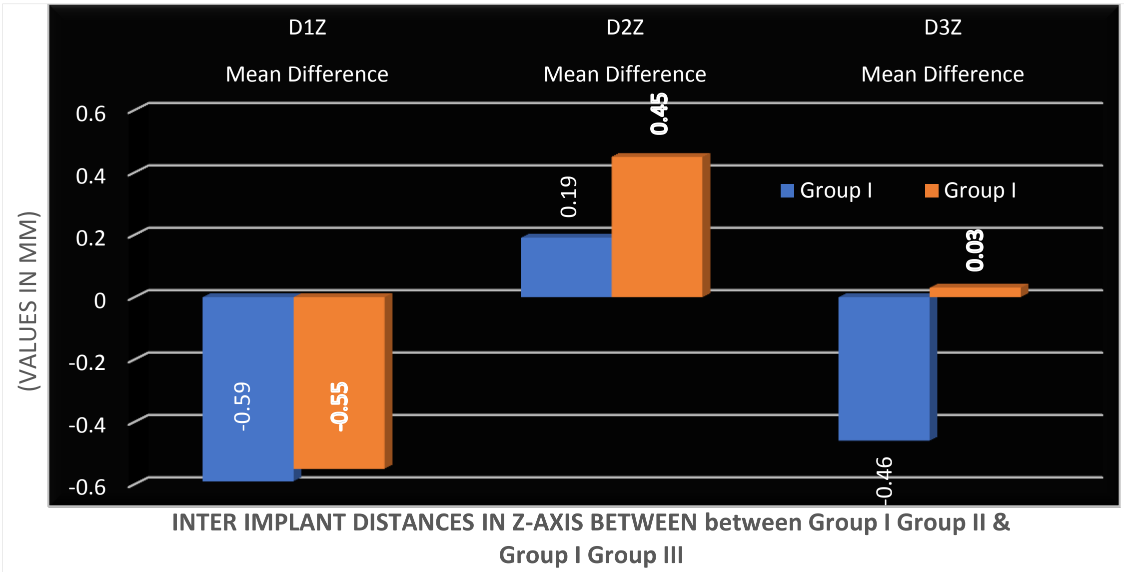
Graph 10b: Comparative evaluation of inter implant distances in Y-axis between Group II and Group I & Group II and Group III



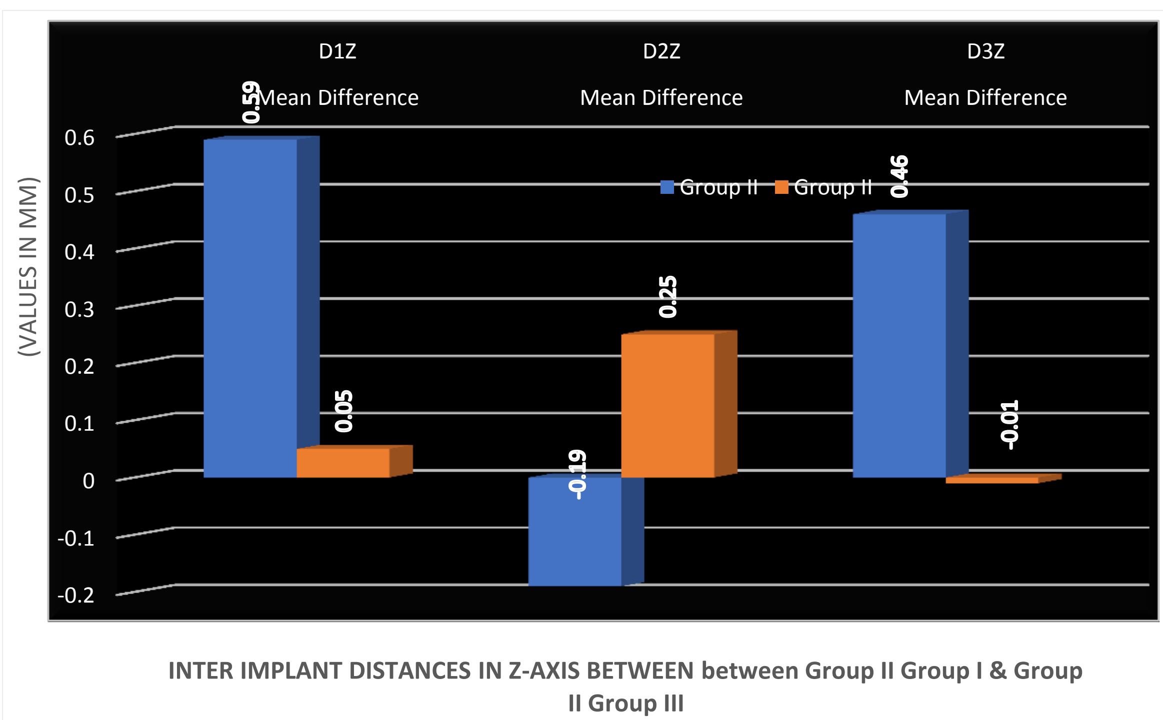
Graph 10c: Comparative evaluation of inter implant distances in Y-axis between Group III and Group I & Group III and Group II



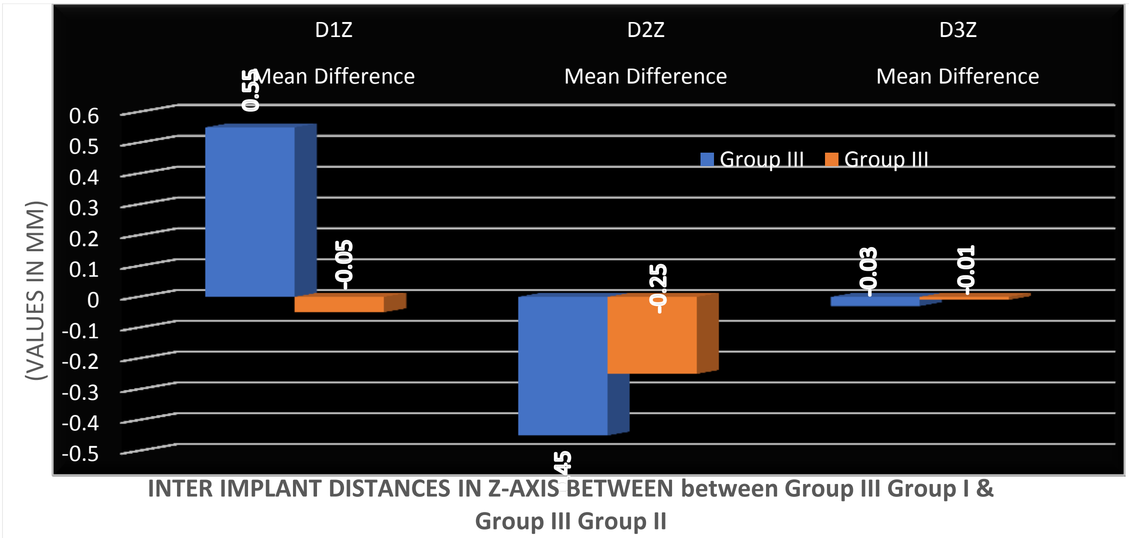
Graph 11a: Comparative evaluation of inter implant distances in Z-axis between Group I and Group II & Group I and Group III.



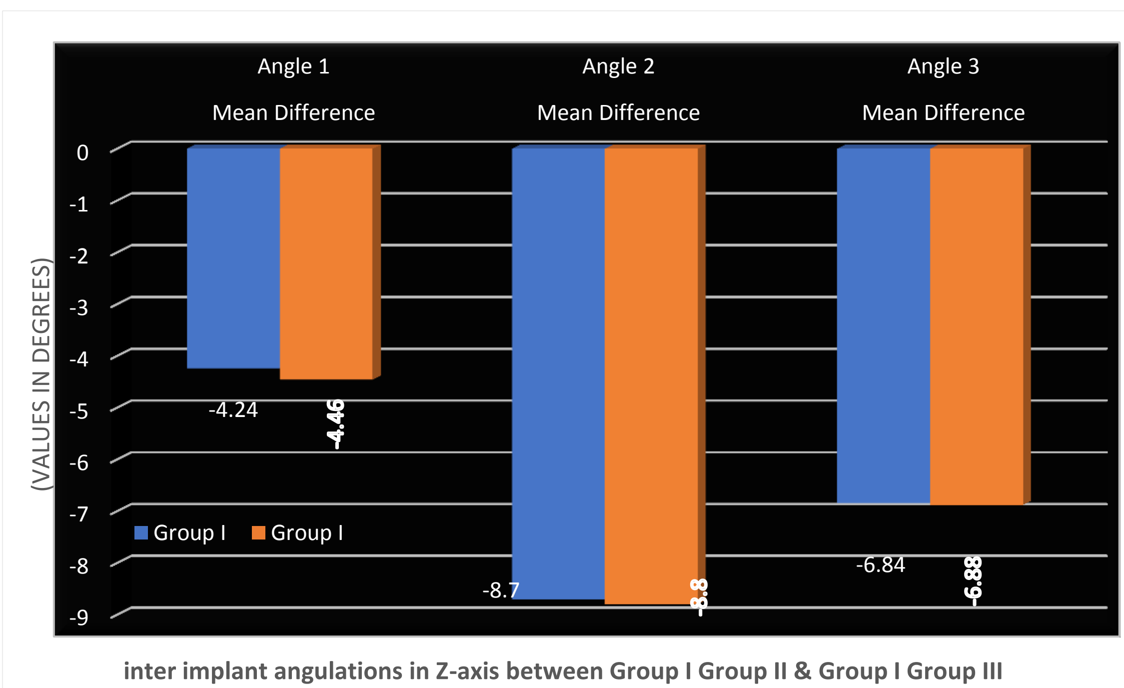
Graph 11b: Comparative evaluation of inter implant distances in Z-axis between Group II and Group I & Group II and Group III



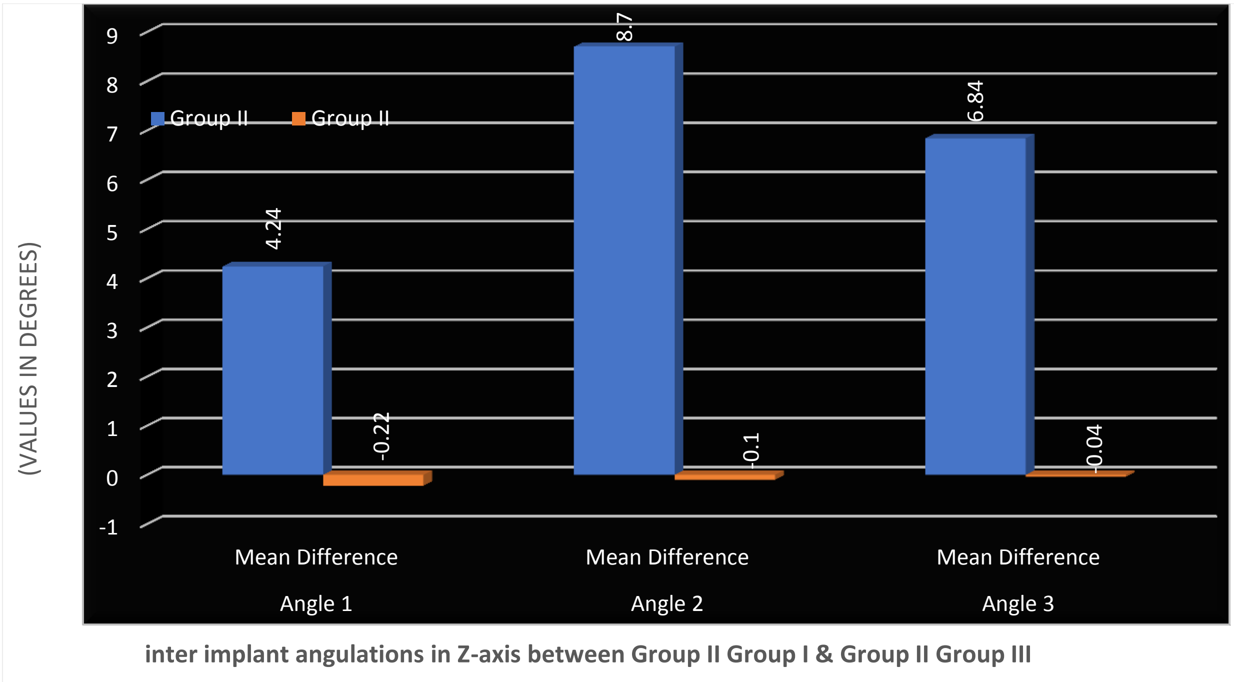
Graph 11c: Comparative evaluation of inter implant distances in Z-axis between Group III and Group I & Group III and Group II



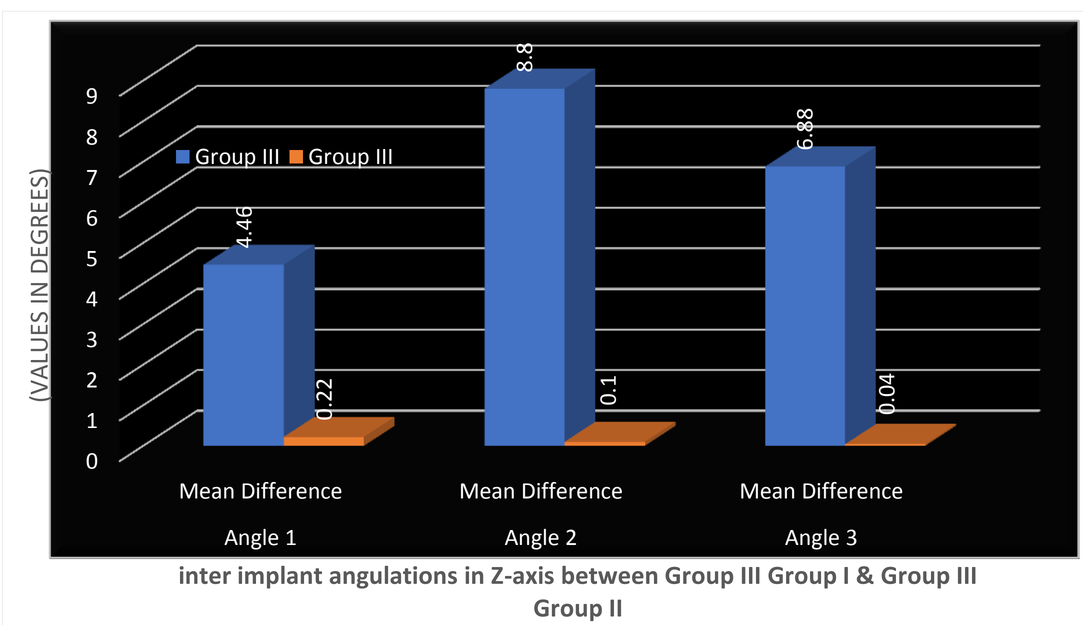
Graph 12a: Comparative evaluation of inter implant angulations in Z-axis between Group I and Group II & Group I and Group III



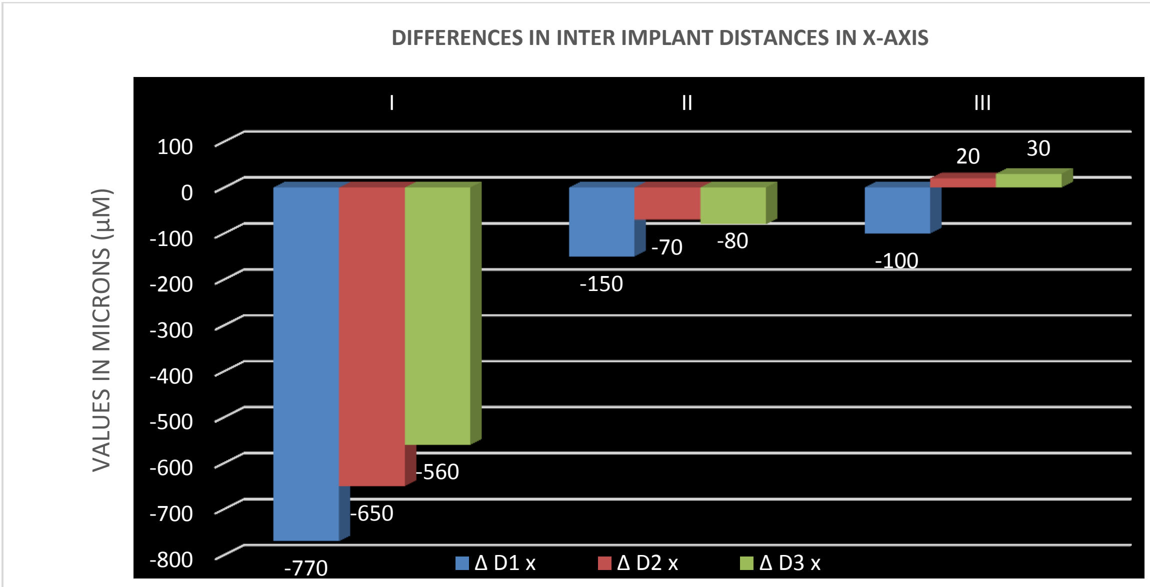
Graph 12b: Comparative evaluation of inter implant angulations in Z-axis between Group II and Group I & Group II and Group III



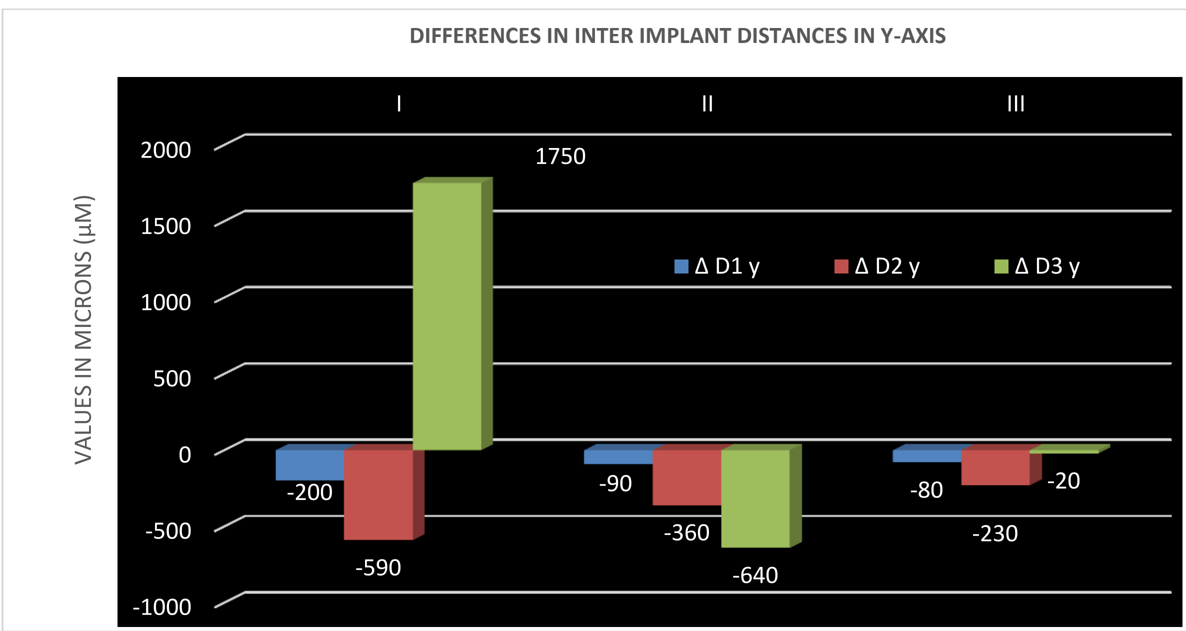
Graph 12c: Comparative evaluation of inter implant angulations in Z-axis between Group III and Group I & Group III and Group II



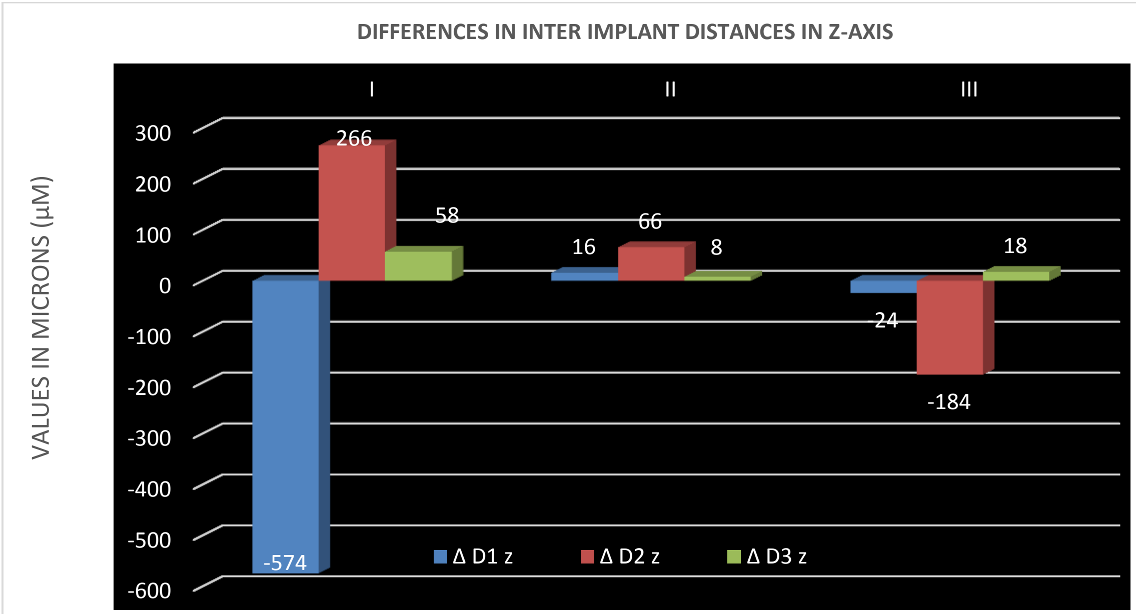
Graph 13a: Differences in inter implant distances in X-axis



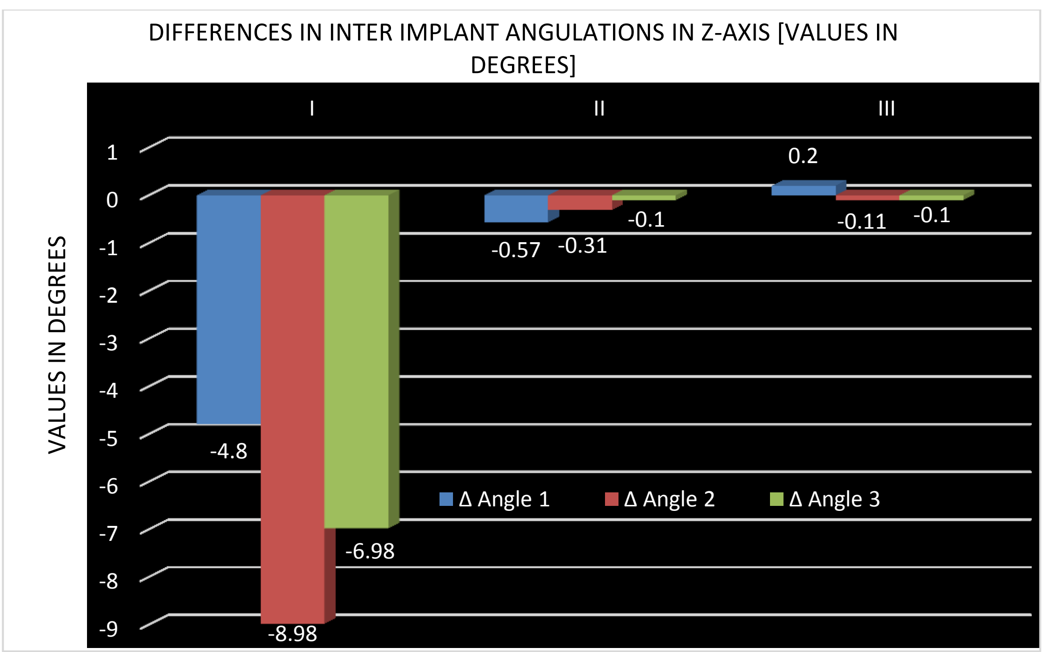
Graph 13b: Differences in inter implant distances in Y-axis



Graph 13c: Differences in inter implant distances in Z-axis



Graph 13d: Differences in inter implant angulations in Z-axis



Discussion

DISCUSSION

Advances in Implant Dentistry have undergone paradigm shift from the initial surgical protocol of placing vertical implants to accommodate the fully edentulous arches even if it necessitated bone augmentation, grafting and sinus lift. Besides the ten years of successful survival rate in such planning, the problem was routinely attributed to long span distal cantilever accommodating the posterior teeth replacement. Secondly, additional regenerative procedures increased the surgical morbidity and the cost factor.[41] Angulating distal implants were hence practiced and shown to be successful in the literature. Literature states that the use of tilted implants as distal abutments is biomechanically superior compared to the use of distal cantilevers. Tilting the posterior implants does not increase the stress compared to those placed vertically.[6,8,87]

The *All-on four* treatment approach maximises the use of available atrophic bone by using long distal implants and compensates the anterior – posterior (AP spread), thereby, avoids anatomical structures, increasing implant to bone contact, good prosthetic support with shorter cantilever arm, coupled with cross arch stabilization and also provides maximum cortical bone engagement with minimum bone volume thereby increasing primary stability.[7,41,53,97]

The angles of distal tilted implants are corrected by utilizing multiunit abutments of varying angles, from straight to 35° to allow single path of insertion. According to photo elastic study by Kim[76], the magnitude of stress or strain for angulated implants decreases or is within the physiologic limits when placed on two distal implants in a curved arch. Begg et al[127] did a qualitative descriptive analyses of stress patterns around the distal angled implants in an All-on-four concept and found little difference in stress pattern between straight and distally angled implants.

By using *All-on- four* treatment protocol, patients benefit with immediate implant supported all acrylic restoration, as provisional restoration is screwed directly and torqued up to 15Ncm into the implants after surgery. After the three month appointment, definitive prosthesis is fabricated.[97,126]

Achieving a passive fit framework is critically significant in a long term successful osseointegration. On the other hand, implant prosthetic misfit can lead to unfavourable complications. Therefore, it is necessary to minimise the misfit to as less as 150µm[12,69] and improve the passive fit for long term implant survival. The implant superstructure misfit is a result of positional distortions that occur in each stage of prosthetic fabrication procedure. These distortions at each stage can be summed to a resultant distortion, called as distortion equation. Therefore theoretically, passivity can be achieved when summation of distortion equation is zero.[134]

In this study, an edentulous mandibular phototopic polymer model was obtained by 3D printing using a complete edentulous clinical situation where *All-on- four* treatment protocol can be benefitted. Surgical guide was fabricated with photocurable acrylic resin designed by 3D printing on this model for the purpose of placing implants in an all-on-four situation. With the help of surgical guide positioned on the reference model, two implant analogs were placed anteriorly and the posterior implant analogs were distally tilted following the drilling protocol.

Four multiunit angled abutments were attached to the implant analogs. Two straight multiunit abutments were placed on anterior implant analogs. One of the distal implants in the left quadrant was corrected by using 17° and the one in right quadrant angulated at 30°. Guide pins were attached to the angulated abutments to assess single path of insertion. Open tray impression copings were attached to the multiunit abutments and torqued to 15 Ncm with the aid of calibrated torque wrench.

Errors in impression making can be introduced in many ways such as lack of parallelism between implants resulting in rotational error that occurs when implants are connected to the impression copings and the dislodgement of the impression material during removal of the impression tray from the oral cavity. These errors result in an inaccurate working cast.[14,45,48,53,80] In order to reduce the distortion; the implants are splinted with a rigid material.[45] Thereby, the need to evaluate the positional accuracy of multiple implants on definitive casts using various splinting materials comes into highlight.

There are studies suggesting that direct (open tray) impression technique produces less distortion than indirect (closed tray) impression technique. The rotation of impression copings in the impression in a direct impression technique is a major drawback to obtain accurate working cast and prosthesis fit.[38,45,63,121] Branemark *et al*[31] has emphasized the importance of splinting impression copings together before the impression procedure for multiple implants. Splinting ensures stabilisation of impression copings when the analogs are fastened and also it reduces rotational freedom within a resilient impression material. So splinting has shown to be a determining factor for fabrication of the most accurate cast regardless of the impression material used.[12,13,33,38,40,96]

In this study; medium body polyether (3M ESPE, Germany) was hand mixed and loaded onto the tray, also delivered between the impression copings for taking multiple impressions for fabrication of working casts. It was handled by one person so as to minimise the uneven impression mixing errors. Polyether has been advocated for edentulous multiple implant retained restorations due to its excellent resistance to permanent deformation, low strain under compression and high tear resistance.[12,38,63,67,135] The rigidity of polyether holds the copings in their position during the forceful removal of impression, thus preventing incidental displacements and ensuring a minimal positional distortion between the laboratory components.[10,105,106]

Three splinting techniques were evaluated in this study with a direct impression method, namely, floss reinforced with pattern resin, floss reinforced with super low flow flowable composite and splinting with orthodontic wire of 19 gauge sectioned and placed between the copings and affixed with Universal bonding agent. Resin has been suggested in many studies[12,13,14,25,33,36,61,63,65,67,93,105,130,136] as a splinting material although there had been contradicting results.[12,13,65,130,136] GC Pattern resin has been used in this study, as it is predominantly used in clinical practice for chair side splinting due to its faster set, lack of need for light curing unit and accurate results obtained in few studies.[17,93,98,105,132] However, splinting with acrylic resin is time consuming and also it has the threat of monomer that can jeopardize the healing course of a recently operated site.[33,46,47,61,63,67,131] Alternatively studies have advocated the use of prefabricated composite bars, flowable composite, restorative resin material (Protemp 1V) where the findings were found to be not statistically significant and were in par with that of pattern resin.[13,66,71,98,115]

A newly launched super low flow flowable composite resin was used to reinforce the dental floss in Group II. This material was based on a new catalyst technology; Radical amplified photo-polymerization initiator (RAP technology) as it cures fast one-third of the time generally required as compared to conventional flowable composite resin. 'Super Low' has low flowability, viscous, non-flaccid, and has precise filling properties that enable the material to be stable in ambient light compared to other products in spite of curing in less exposed time. According to the technical report,[99] super Low flow flowable composite had shown minimal linear polymerisation shrinkage compared to other commercially used flowable composites. This was claimed to be due to high filler volume i.e., 56 vol% by combining supra-nano spherical filler and newly developed composite filler. Low flow with superior handling properties attracted our interest to evaluate the use of this material as a splinting material. Also, by using light polymerised composite resin, problems of polymerisation contraction are minimised as compared to problems faced by the autopolymerising acrylic resin and the procedure reduces the time consuming factor.

In few of the studies, Metal splinting used as a splinting material in the form of stainless steel wire reinforced with acrylic resin, metal cylinders used around impression copings in combination with impression plaster, metal shanks of burs sectioned and placed between impression copings and attached with cyanoacrylate and pattern resin to minimise distortion has been compared with other conventional methods. [48,63,89,93,112]Through these studies, it was found that metal splinting provided more significant accurate impressions than non-splinting and over different splinting techniques.[48,89,112] Therefore, we understood the need to use the metal splint as an alternative method to check the accuracy of impression transfer as Group III. One of the criteria in choosing orthodontic wire of 19 gauge thickness was its width and rigidity which is the prerequisite of a splinting material[48] and no scope for shrinkage ensures minimum or no distortion with the casts obtained. Easy availability of 19 gauges in clinical practice and its cost effectiveness made us choose this material to evaluate its benefits as a splinting material. There are studies where stainless steel wire affixed with small increments of Duralay resin or metal shanks of the burs affixed to the copings with cyanoacrylate and Duralay[48] showed that metal splinting gives better results than resin splinting. However, using cyanoacrylate can cause irritating reactions to the mucosa.[82]In this study; we have focussed on using a universal bonding agent which had high bonding strength to metal and ensures a clean and easy chair side procedure.

In this study, we used the orthodontic wire affixed with a newly introduced universal bonding agent which has high stable bond strength and durability. This universal bonding agent contains new adhesive monomer 3D-SR (phosphoric acid monomer), MTU-6 (6-methacryloyloxyhexyl 2-thiouracil-5-carboxylate and y-MPTES (y-methacryloxypropyl triethoxy silane). For a non-precious metal, the phosphate group of new 3D-SR monomer interacts with the oxygen atom of the passive layer of a non-precious metal surface and forms a bond between metal to metal components. Research reporting these materials are inadequate and there by the primary reason in choosing this bonding agent for splinting was to evaluate the positional accuracy of impression coping with a simplified clinical procedure.[100,101]

The spacer thickness was made up to 3mm in the reference model and an irreversible hydrocolloid impression was made to make the spaced primary cast. Ten impressions were made in each group using customised special trays. The custom trays were standardized by having even thickness of 2mm, were adapted on the spaced primary cast to ensure even thickness and rigidity of the resin sheet. The special tray and the impression copings were coated with polyether adhesive to prevent the distortion of impression and also to minimise the rotational errors of the long handles of the copings while removing from the impression. The tray was loaded with the impression and placed along the reference model for impression making. The open tray impression copings were connected to implant analog-multiunit abutment assembly and tightened.

All casts were poured with the same amount of measurement of die stone as per the manufacturer’s instruction. All the casts were measured on a three dimensional basis using a coordinate measuring machine (CMM) with an accuracy of ±0.05. Inter implant distances in x, y and z axes and inter implant angulation in z axis were compared and evaluated for the reference model and all the test groups. All casts were measured by keeping the implant analog 1 as the reference model to calculate the relative distortion.

The results were divided into four categories like distortions in x, y and z axes and the inter implant rotational distortion. A total of 9 distances and three angles were compared and evaluated separately to analyse where the distortion happens the most.

The inter implant distances of D1x (distances between implant analog 1 and implant analog 2), D2x (distances between implant analog 1 and implant analog 3) and D3x (distances between implant analog 1 and implant analog 4) were not statistically significant from reference model to test groups I, II and III. The range of differences was seen the least in Group III, orthodontic wire affixed with universal bonding agent and maximum differences was observed in Group I in x-axis. Group II i.e., floss reinforced with super low flow flowable composite and Group III orthodontic wire affixed with universal bonding agent were of similar ranges and more similar with reference model. The differences in inter implant distances in x-axis ranged from **-560µm to -770µm** for resin splinted impression copings**,-150µm to -80µm** for impressions with floss reinforced super low composite resin splinted impression copings and impressions with metal splinting affixed with universal bonding agent ranged from **30µm to -100µm.**

The inter implant distances of D1y (distances between implant analog 1 and implant analog 2), D2y (distances between implant analog 1 and implant analog 3) and D3y (distances between implant analog 1 and implant analog 4) were not statistically significant from reference model to test groups I, II and III. The range of differences was seen the least in Group III, and maximum differences were observed in Group I in y-axis. Maximum differences were seen in D2y and D3y variables of pattern resin splinting (Group I) and composite resin splinting (Group II) where posterior angled implant was compared with anterior vertical implant and the least differences were seen in metal splinting (Group III). The differences in the inter implant distances in y-axis ranged from **1750µm to -200µm** for impressions with pattern resin splinted, **-640µm to -90µm** for impressions with composite resin splinted and **-20µm to -80µm** for impressions with metal splinting affixed with universal bonding agent. The differences were more evident in y-axis than x-axis in case of pattern resin as well as composite resin splinting. The maximum amount of distortion was seen in floss reinforced with pattern resin (Group I) than the floss reinforced with super low flow flowable composite (Group II).

The inter implant distances D2z (distances between implant analog 1 and implant analog 3) and D3z (distances between implant analog 1 and implant analog 4) were not statistically significant from reference model to test groups I, II and III. However, D1z (distances between implant analog 1 and implant analog 2), of pattern resin splinting group (Group I) had shown statistically significant results compared to reference model. The differences in the inter implant distances in z-axis ranged from **-574µm to 58µm** for impressions with pattern resin splinted, **-66µm to -8µm** for impressions with composite resin splinted and **18µm to -24µm** for impressions with metal splinting affixed with universal bonding agent. The range of differences was seen the least in Group III, orthodontic wire affixed with universal bonding agent and maximum differences was observed in acrylic resin splinting (Group I) in z-axis.

On comparison of the inter implant angulations with the reference model, Group II & Group III did not reveal statistically significant differences. Group I showed greater deviation from the reference model which was statistically significant that also corresponded to the distortion analyzed in µm, ranging from **-8.98° to -4.8°**

When comparing between the groups I, II and III by using One way ANOVA, statistically significant results between the groups were seen for D3x, D3y, D1z, Angle 1, Angle 2 and Angle 3 values.

With Post Hoc HSD Tukey's test analysis, it was observed when comparing between the groups I, II and III, in x-axis, D3x, (i.e., distance between implant analogue 1 and implant analogue 4) showed statistically significant results between group I and III. **(0.046*)** This was further substantiated by observing the distortion values in D3x between group 1 (**-560µm**) and group III (**30 µm**).

When comparing between the groups I, II and III, in y-axis, D3y, (i.e., distance between implant analogue 1 and implant analogue 4) showed statistically significant results between group I and II. **(0.008*)** This was further substantiated by observing the distortion values in D3y between group 1 **(1750 µm)** and group II **(-640 µm**)

When comparing between the groups I, II and III, in z-axis, D1z, (i.e., distance between implant analogue 1 and implant analogue 2) showed statistically significant results between group I and II **(0.002*)** & group I and group III. **(0.005*)** This was further substantiated by observing the distortion values in D1z between group 1 **(-574 µm)** and group II **(16µm**) & group I **(-574 µm)** and group III **(-24 µm)**

When comparing inter implant angulations between the groups I, II and III, in z-axis; angle 1, angle 2 and angle 3 (i.e., angles between implant analog 1 and implant analog 2, 3 and 4) showed statistically significant results between group I and II & group I and group III. This was further substantiated by observing the distortion values in inter implant angulations in z-axis between group 1 **(-4.8°)** and group II **(-0.57**°) & group I **(-4.8 °)** and group III **(0.2 °)** in angle 1. Distortion values for angle 2 between group 1 **(-8.98°)** and group II **(-0.31**°) & group I **(-8.98 °)** and group III **(-0.11 °)** also corresponded to the significance seen. Distortion values for angle 3 was observed between group 1 **(-6.98°)** and group II **(-0.1**°) & group I **(-6.98 °)** and group III **(-0.1 °)**.

Rotational distortion were seen in the z-axis ranged from **8.98° to 4.8°** for pattern resin splinting, **0.1° to 0.57°** for floss reinforced with super low flow flowable composite and **0.1° to 0.2°** for metal splinting with universal bonding agent. Maximum distortion was seen in floss reinforced with pattern resin (Group I) and the least distortion was seen in orthodontic wire affixed with universal bonding agent (Group III).

In the present study maximum deviation from the reference model was seen with pattern resin group followed by super low flow composite and stainless wire affixed with bonding agent accordingly. Though statistically significant results were seen with group 1, group 2 also showed greater deviations in y axis which was however not statistically significant. Group 3 showed values closer to that of the reference model and hence better reproducibility.

Several studies have evaluated the use of pattern resin showing results comparable to that of present study. Similar distortion results were seen in studies not supporting the technique of splinting with autopolymerising acrylic resin.[33,51,67,90]

Francisco et al[89] showed greater distortion of acrylic resin splinted technique with 84.30µm followed by metal splinting technique 38.23µm. Studies by Humphries et al, Hsu et al and Herbst et al, Selvaraj et al, Thara et al have shown no significant results between acrylic resin splinted and other splinting materials.[61,63,65,71,115]

In the present study, metal splinting showed least errors than the acrylic resin or the composite resin group. This is in accordance with the study conducted by Lee *et al*[80] and Saboury *et al*[112] reports that metal splinted open tray impression technique with two implants placed at an angulation of 30° showed superior impression accuracy compared to other splinting materials.

Study by Ibrahim *et al*[66] and Kamrani *et al*[72] reports that splinting impression copings with light cure flowable composite resin show accurate results as compared with acrylic resin or other splinting techniques. In a similar study by Thara *et al*[71], splinting with flowable composite has been suggested as a material of choice for multiple implants as they have yielded similar results of accuracy in par with pattern resin. Study by Ongul *et al*[98] have shown prefabricated acrylic bars when used as splinting material shown less deviation from master casts when compared light cure composite resin.

Through various analyses done, impressions with super low flow flowable composite and orthodontic wire affixed with universal bonding agent showed similar values as compared with floss reinforced with pattern resin.

The angular differences could be due to possible angulated implant taken as reference, and rotation distortion seen while removing the impression coping from the implant analogue. In this study, only finger pressure was used to tighten the impression copings and not torqued as repeated torqueing can fracture the prosthetic components and possible error of rotation of impression coping in impression.

Studies of 1.6 to 5.3 degree tolerance was measured with different implant abutment matings and the existence of rotational freedom of 5.5° between implant and abutment suggest that the values obtained for Group II (**0.1° to 0.6°)** and Group III (**0.1° to 0.2°)** were within our clinical acceptable values. However, the values obtained for impression with pattern resin splinting had shown rotational distortion of **4.8°** to **9°** which is not clinically acceptable.

The overall accuracy of impression depends on all the four parameters. The distortion of impression in three dimensional can be evaluated as absolute or relative. Depending on the reference point, if it’s external the absolute distortion is considered. If the point of reference is internal, the relative distortion is considered where the point is within the working piece. In the present study, we had considered relative distortive analysis as the study parameter for measuring the transitional distance between one coping to another just like in few studies. This can be considered as relevant measuring distortive analysis as the copings are connected to each other in the oral cavity.[25,59,105,121,135]

There are few studies which has shown that splinting pattern resin and then sectioning and joining with small increments of acrylic resin minimises the polymerisation shrinkage and use of prefabricated acrylic bar can improve the accuracy of impression transfer. In our study, the errors in splinting pattern resin group can be attributed to the shrinkage of the splinting material and also non-sectioning of the pattern resin material between the impressions copings. Studies with non-sectioned and sectioned pattern resin as a splinting material has shown conflicting results. Studies have showed that sectioning of pattern resin after splinting and then re-joining them with small increments of pattern resin can minimise the polymerization shrinkage.[4,36] If preformed acrylic bars were perhaps used as splinting material as supported by few studies, could have probably given us more accurate reproduction of multiple implant impression copings as compared to direct acrylic splinting technique.[1,42,56,91,131]

We had chosen direct splinting technique with pattern resin as one of the conventional splinting material so as to compare with other splinting materials which emphasizes on lesser chair side time and easy handling and hence no sectioning and resplinting was done.

The range of differences for super low flow flowable composite was seen in y-axis than the other axes. This could be due to incomplete polymerisation of light cured resin or likely due to intensity of light curing unit that can influence the adaptation of composite resin to the impression copings. The differences in the groups were within the clinical accepted value unlike pattern resin.

Lesser distortion values were observed in metal splinting i.e., using of orthodontic wire affixed with universal bonding agent followed by splinting dental floss reinforced with flowable composite. The results of the study indicate that super low flow flowable composite and orthodontic wire affixed with universal bonding agent can be used for splinting multiple angulated implants since it falls well within the clinically accepted discrepancy of up to 150µm[12,69]and they are rigid, easy in handling, cost effective and less time consuming.

Since flowable composite and metal splinting have not been used in many studies and the use of a newly launched super low flow flowable composite and universal bonding agent as a splinting material in the literature is definitely lacking, these values obtained in the study, is to be compared with pattern resin splinting only. The values obtained for super low flow flowable composite and the orthodontic wire affixed with universal bonding agent is in lieu with the reference model indicating that the material can be used as a splinting material and the accuracy rate is satisfactory for situations involving angulated implants. Further studies are needed to be evaluated with sectioning of pattern resin after splinting technique and also with pre sectioned acrylic bar.

The usage of super low flow flowable composite as a splinting material yielded positive results in our study for splinting. Further studies highlighting the accuracy of impression techniques by testing it with other flowable composites is needed.

The findings observed in all three axes showed accurate reproduction of inter implant distances and angulations in one or more axes, but not in all three axes. If there is significant differences in any axes, not necessary the differences to be present in all axes. The errors can occur due to positional changes in any three axes resulting in compromise of prosthetic misfit.

The comparative evaluation of the effect of orthodontic wire affixed with universal bonding agent splinted between impression copings with implant impression transfer on All- on- four treatment protocol had shown closer accuracy to the reference model. This material being easily available in a clinical practice, economical, less time consuming and not requiring any elaborate procedures like pattern resin splinting emphasizes the superiority of the material to be used for the splinting technique. The results of our study were seen in agreement with previous studies. [48,89,112]

The results obtained in this study are in vitro and so further clinical studies are to be evaluated in relation to intraoral conditions and the materials used for splinting.

Conclusion

CONCLUSIONS

The following conclusions were drawn from the data obtained in the present *in vitro* study that was conducted to comparatively evaluate the effects of splinting materials, i.e., Floss reinforced with pattern resin, Floss reinforced flowable composite and orthodontic wire affixed with universal bonding agent with implant impressions on All-on-four treatment protocol:

1. For reference group, in x-axis, the mean values obtained for D1x was **8.53**, D2x was **17.64** and D3x was **29.29**. In y-axis, the mean values obtained for D1y was **10.70**, D2y was **14.77** and D3y was **7.751**. In z-axis, the mean values obtained for D1z was **1.184**, D2z was **1.214** and D3z was **-0.208**. In z-axis, the mean values obtained for Angle 1 was **44.47**, Angle 2 was **77.11** and for Angle 3 was **114.74**.
2. For Group I, in x-axis, the mean value obtained for D1x-axis was **7.76**, D2x was **16.99** and D3x was **28.83**. In y-axis, the mean value obtained for D1y was **10.50**, D2y was **10.44**, and D3y was **10.62**. In z-axis, the mean value obtained for D1z was **0.61**, D2z was **1.20** and for D3z was **1.03**. In z-axis, the mean values obtained for Angle 1 was **39.67**, Angle 2 was **68.13** and for Angle 3 was **107.71**.
3. For Group II, in x-axis, the mean value obtained for D1x-axis was **8.39**, D2x was **16.71**, and D3x was **28.73**. In y-axis, the mean value obtained for

D1y was **10.44**, D2y was **13.81**, and D3y was **5.75**. In z-axis, the mean value obtained for D1z was **0.61**; D2z was **1.28** and for D3z was **-0.09**. In z-axis, the mean values obtained for Angle 1 was **43.91**, Angle 2 was **76.85** and for Angle 3 was **114.27**.

4. For Group III, in x-axis, the mean value obtained for D1x-axis was **8.43**, D2x was **17.66** and D3x was **29.32**. In y-axis, the mean value obtained for D1y was **10.62**, D2y was **13.94**, and D3y was **6.37**. In z-axis, the mean value obtained for D1z was **1.16**; D2z was **1.03** and for D3z was **-0.19**. In z-axis, the mean values obtained for Angle 1 was **44.3,** Angle 2 was **76.96** and for Angle 3 was **114.57**.
5. On comparison with the reference model all the three test groups did not reveal statistically significant differences in x-axis and y-axis. With Group III having least deviation followed by Group II and Group I having greater deviation from the reference model.
6. On comparison with the reference model Group II & Group III did not reveal statistically significant differences in z-axis. While Group I **(28.73)** showed greater deviation from the reference model **(29.29)** in D1z axis which was statistically significant ($p<0.05$) and distortion being **-574µm.**
7. On comparison of the inter implant angulations with the reference model, Group II & Group III did not reveal statistically significant differences. Group I showed greater deviation from the reference model which was

statistically significant ($p<0.05$). This also correspond to the distortion analyzed in µm and ranged from **-8.98° to -4.8°**

8. When comparing between the groups I, II and III by using **One way ANOVA**, statistically significant results between the groups were seen for D3x, D3y, D1z, Angle 1, Angle 2 and Angle 3 values.
9. With **Post Hoc HSD Tukey's test analysis,** it was observed
    - When comparing between the groups I, II and III, in x-axis, D3x, (i.e., distance between implant analogue 1 and implant analogue 4) showed statistically significant results between group I and III. **(0.046*)** The mean inter implant distance in D3x- axis of Group III **(29.32)** was closer to reference mean value **(29.29)** compared to Group I. **(28.73)** This was further substantiated by observing the minimal distortion values in D3x with group III (**30 µm**) compared to group 1 (**-560µm**). The inter implant distances of group I and group II & group II and group III in D1 and D2x-axes were found to be clinically insignificant.
    - When comparing between the groups I, II and III, in y-axis, D3y, (i.e., distance between implant analogue 1 and implant analogue 4) showed statistically significant results between group I and II. **(0.008*)** The mean inter implant distance in D3y- axis of Group II **(6.37)** was closer to reference mean value **(6.39)** compared to

Group I. **(8.14)** This was further substantiated by observing the distortion values in D3y with group 1 **(1750 µm)** and group II **(-640 µm**). The inter implant distances in D1y-axis and D2y-axis for groups I and III & groups II and III were found to be insignificant.

- When comparing between the groups I, II and III, in z-axis, D1z, (i.e., distance between implant analogue 1 and implant analogue 2) showed statistically significant results between group I and II **(0.002*)** & group I and group III. **(0.005*)** This was further substantiated by observing the distortion values in D1z between group 1 **(-574 µm)** and group II **(16µm**) & group I **(-574 µm)** and group III **(-24 µm).** The inter implant distances in D2z-axis and D3z-axis for groups II and groups III were found to be insignificant.
- When comparing inter implant angulations between the groups I, II and III, in z-axis; angle 1, angle 2 and angle 3 (i.e., angles between implant analog 1 and implant analog 2, 3 and 4) showed statistically significant results between group I and II & group I and group III. This was further substantiated by observing the distortion values in inter implant angulations in z-axis between group 1 **(-4.8°)** and group II **(-0.57°**) & group I **(-4.8 °)** and group III **(0.2 °)** in angle 1.

Distortion values for angle 2 between group 1 **(-8.98°)** and group II **(-0.31°**) & group I **(-8.98 °)** and group III **(-0.11 °)** also corresponded to the significance seen. Distortion values for angle 3 was observed between group 1 **(-6.98°)** and group II **(-0.1°**) & group I **(-6.98 °)** and group III **(-0.1 °)**. The inter implant angulations of Group II and Group III in z- axis were found not to be significant.

10. Among the splinting materials, splinting with Group III yielded master casts closer to reference model, followed by Group II, and Group I.
11. Impressions made with floss reinforced with pattern resin splinting with direct impression copings yielded master casts that exhibited differences in inter implant distance in range of -**560µm to -770µm** in x-axis, **1750µm to -200µm** in y-axis, **-574µm to 58µm** in the z-axis and -**8.98° to -4.8°** deviation in inter implant angulation when compared to reference model, these differences weren't within clinically acceptable limits (150µm).
12. Impressions made with floss reinforced with flowable composite splinted with direct impression copings yielded master casts that exhibited differences in inter implant distance in range of **-150µm to -80µm** in x-axis, **-640µm to -90µm** in y-axis, **-66µm to -8µm** in the z-axis and **-0.1° to -0.57°** deviation in inter implant angulation when compared to

reference model, these differences were within clinically acceptable limits (150µm).

13. Impressions made with orthodontic wire affixed with universal bonding agent splinted with direct impression copings yielded master casts that exhibited differences in inter implant distance in range of **30µm to -100µm** in x-axis, **-20µm to -80µm** in y-axis, **18µm to -24µm** in the z-axis and **-0.1° to 0.2°** deviation in inter implant angulation when compared to reference model, these differences were within clinically acceptable limits (150°).

Summary

SUMMARY

The present in vitro study compared and evaluated the effect of three splinting materials, namely, floss reinforced with pattern resin, floss reinforced with flowable composite and orthodontic wire affixed with universal bonding agent with open tray impression copings for the positional accuracy of implants in x, y, z axes and inter implant angulations for an *All–on-four* treatment protocol

A reference mandibular model with four implant analogs with the aid of surgical guide were placed according to All-on-four treatment protocol. Multiunit abutments and open tray impression copings were attached to the implant analogs and torqued. The custom trays were fabricated to make impressions with polyether impression material. Thirty impressions were totally made after splinting the impression copings and divided into three groups based on technique used for splinting (n=10/group) i.e. Group I Floss reinforced with pattern resin splinted open tray implant impression transfer, Group II Floss reinforced with flowable composite splinted open tray implant impression transfer, and Group III orthodontic wire affixed with universal bonding agent. The impressions were poured with type IV dental stone and the master casts obtained. The reference model and master casts were analyzed for three dimensional accuracy of inter

implant relationship using coordinate measuring machine in three axes, x-axis, y-axis and z-axis and inter-implant angulations.

The results were tabulated and statistically analyzed using one sample T-test, one way ANOVA and Post-hoc Tukey's test. The differences in the inter implant distances in x, y and z axes and the inter implant angular differences around z-axis between the reference model and the master casts were analysed. The differences in between the groups in each x, y and z axes were also analyzed.

Statistical analysis revealed, significant results in z-axis with respect to D1z and all inter implant angulations for Group I master casts when compared with the reference model. Mean of Group II and Group III master casts showed differences with the reference model which was not statistically significant. The values of the Group III were closer to that of reference model in all dimensions.

When comparing between the groups I, II and III, One way ANOVA test analysis revealed statistically significant results between groups for D3x, D3y, D1z, angle 1, angle 2 and angle 3.

Post hoc Tukey's HSD test analysis revealed statistical significant differences between group I & group III in D3x-axis, between group I & group II in D3y-axis, between groups I and II & groups I & III in D1z-axis and inter implant angulations angle 1, angle 2 and angle 3.

The master casts (Group III) made with orthodontic wire affixed with universal bonding agent direct splinted copings were the closet to the reference model followed by master casts (Group II) from impressions made with floss reinforced with flowable composite and then the direct splinted pattern resin technique (Group I). In this study, the difference in inter implant relationship were within the clinically accepted values for flowable composite and orthodontic wire but not within the limit for that of pattern resin splinted technique.

Both Group II and Group III have shown better reproduction of the reference model signifying that floss reinforced with super low flow flowable composite and orthodontic wire affixed with universal bonding agent can be used as efficient splinting materials for direct impression techniques. Hence, it is suggested to select the splinting technique based up on the clinical situation, ease of usage, preference and expertise of the clinician. Further studies engaging prefabricated acrylic rods and different flow of flowable composite resin are recommended to enhance the results of our study.

Bibliography

BIBLIOGRAPHY

1. **Aghandeh R, Rasaeipour S, Ghodsi S.** Introducing a method to facilitate making acrylic resin bars for splinting multiple implant impression copings. World J Dent 2018;9(1):76-78
2. **Akça K, Cehreli MC.** Accuracy of 2 impression techniques for ITI implants. Int J Oral Maxillofac Implants 2004;19(4):517-23.
3. **Alikhasi M, Bassir SH, Naini RB.** Effect of multiple uses of impression copings on the accuracy of implant transfer. J Oral Maxillofac Implants 2013;28:408-14
4. **Al-Quran FA, Rashdan BA, Abu Zomar AA, Weiner S.** Passive fit and accuracy of three dental implant impression techniques. Quintessence Int 2012;43:119–125.
5. **Anandh B, Lokesh B, Ebenezer V, Jimson S, Parthiban J.** All on four- The basics. Biomed. & Pharmacol. J., 2015;8: 609-12
6. **Antonios Zampelis.** Tilting of splinting implants for improved prosthodontics support: a two dimensional finite element analysis. J Prosthet Dent 2007;97:s35-43
7. **Aparicio C, Parales P, Rangert B.** Tilted implants as alternative to maxillary sinus grafting; A Clinical, Radiologic, and periotest study. Clin Implant Dent Rel Res 2001;3(1):39-49
8. **Asawa N, Bulbule N, Kakade D, Shah R.** Angulated implants: An alternative to bone augmentation and sinus lift procedure: Systematic review. J Clin Diag Res 2015; 93(3):10-13

9. **Ashley D.** The man behind the success of all-on-four dental implants. U Publish.info2011:1

10. **Assif D, Fenton A, Zarb G, Schmitt A.** Comparative accuracy of implant impression procedures. Int J Periodont Rest Dent 1992;12:113-21.

11. **Assif D. Marshak B, Nissan J.** A modified impression technique for implant supported restoration. J Prosthet Dent 1994;71;589-91

12. **Assif D. Marshak B, Schmidt A.** Accuracy of implant impression techniques. Int J Oral Maxillofac Implants 1996;11:216-222

13. **Assif D. Nissan J, Varsano I, Singer A.** Accuracy of implant impression splinted techniques; effect of splinting materials. Int J Oral Maxillofac Implants 1999; 14:885-888

14. **Assuncao WG, Gennari-Filho H, Zaniquelli O.** Evaluation of transfer impressions for osseointegrated implants at various angulations. Implant Dent. 2004;13:358-66

15. **Assuncao WG, Cardoso A, Gomes EA, Tabata LF, Santos PHD**. Accuracy of impression techniques for implants. Part I- Influence of transfer copings surface abrasion. J Prosthodont 2008;17:641-47

16. **Assuncao WG, Tabata LF, Cardoso A, Rocha EP, Gomes EA.** Prosthetic transfer impression accuracy evaluation for osseointegrated implants. Implant Dent 2008; 17(3):248-56

17. **Assuncao WG, Britto RC, Barao VAR, Delben JA, Santos PHD.** Evaluation of impression accuracy for implant at various angulation. Implant Dent 2010;19(2):167-74

18. **Atwood DA.** Some clinical factors related to rate of resorption of residual ridge. J Prosthet Dent 1962;12(3):441-50

19. **Atwood DA.** Clinical, cephalometric, and densitometric study of reduction of residual ridges. J Prosthet Dent 1971;26(3):280-95

20. **Avila ED, Matos Moraes F, Castanharo SM, Del'Acqua MA, Assis Mollo F.** Effect of splinting in accuracy of two implant impression techniques. J Oral Implantol. 2014 Dec;40(6):633-39.

21. **Avila ED, Castanharo SM, Casalle N, Vasconcelos JA, Assis Mollo F.** Effect of the association between the tray and impression techniques on angulated implants using the All-on-four system. J Oral Implantology 2015;41(S1):382-385.

22. **Baig MR.** Multiunit implant impression accuracy: A review of the literature. Quintessence Int Pros 2014;45(1):39-51

23. **Baig MR, Buzayan MM, Yunus N.** Accuracy of new elastomeric impression material for complete arch dental implant impressions. J Invest Clin Dent 2018;e12320:1-6

24. **Balouch F, Jalalian E, Nikkheslat M, Ghavamian R, Toopchi Sh, Jallalian F, Jalalian S.** Comparison of Dimensional Accuracy between Open-Tray and Closed-Tray Implant Impression Technique in 15° Angled Implants. J Dent (Shiraz). 2013 Sep;14(3):96-102.

25. **Barrett MG, de Rijk WG, Burgess JO.** The accuracy of six impression techniques for osseointegrated implants. J Prosthodont. 1993 Jun;2(2):75-82.

26. **Bedrossian E, Sullivan RM, Fortin Y, Malo P, Indresano T.** Fixed prosthetic implant restoration of the edentulous maxilla: a systematic pretreatment evaluation method. J Oral Maxillofac Surg 2008;66:112-22

27. **Behnaz E, Ramin M, Abbasi S, Pouya MA, Mahmood F.** The effect of implant angulation and splinting on stress distribution in implant body and supporting bone: A finite element analysis. Eur J Dent 2015 Jul-Sep;9(3):311-8.

28. **Beyabanaki E, Shamshiri AR, Alikhasi M, Monzavi A**. Effect of Splinting on Dimensional Accuracy of Impressions Made of Implants with Different Subgingival Alignments. J Prosthodont 2017 Jan;26(1):48-55.

29. **Bhardwaj S, Srivastava R, Palekar U, Choukse V.** The “All-on-4” immediate function concept: A Review. NJDSR 2014;2(1):78-81

30. **Bodic F. Hamel L, Lerouxel E, Basle MF, Chappard D.** Bone loss and teeth. Joint Bone Spine 2005;72:215-221

31. **Branemark PI.** Osseointegration and its experimental background. J Prosthet Dent. 1983 Sep;50(3):399-410.

32. **Brosh T, Pilo R, Sudai D.** The influence of abutment angulation on strains and stresses along the implant/bone interface: Comparison between two experimental techniques. J Prosthet Dent 1998;79:328-34

33. **Burawi G, Houston F, Byrne D, Claffey N.** A comparison of the dimensional accuracy of the splinted and unsplinted impression techniques for the Bone-Lock implant system. J Prosthet Dent 1997 Jan;77(1):68-75.

34. **Burns J, Palmer R, Howe L, Wilson R.** Accuracy of open tray implant impressions: an in vitro comparison of stock versus custom trays. J Prosthet Dent. 2003 Mar;89(3):250-5.

35. **Buzayan MM, Yunus NB.** Passive Fit in Screw Retained Multi-unit Implant Prosthesis Understanding and Achieving: A Review of the Literature. J Indian Prosthodont Soc. 2014 Mar;14(1):16-23.

36. **Cabrel LM, Guedes CG.** Comparative analysis of four impression techniques for implants. Implant Dent 2007;16(2):187-94

37. **Carlsson GE, Persson G.** Morphologic changes of the mandible after extraction and wearing out dentures. Odontol Revy. 1967;18(1):27-54

38. **Carr AB.** Comparison of impression techniques for a two-implant 15-degree divergent model. Int J Oral Maxillofac Implants 1992 Winter;7(4):468-75.

39. **Carr AB, Gerard DA, Larsen PE.** The response of bone in primates around unloaded dental implants supporting prostheses with different levels of fit. J Prosthet Dent. 1996 Nov;76(5):500-9.

40. **Carr AB, Master J.** The accuracy of implant verification casts compared with casts produced from rigid transfer coping technique. J Prosthodont 1996;5(4):248-52

41. **Chan MH, Holmes C.** Contemporary "All-on-4" concept. Dent Clin North Am. 2015 Apr;59(2):421-70.

42. **Chang W, Vahidi F, Bae K, Lim B**. Accuracy of three implant impression techniques with impression materials and stones. Int J Prosthodont 2012;25:44–47.

43. **Choi JH, Kim CH, Jang KS, Lim YJ.** Comparative accuracy of the splinted and unsplinted impression methods for internal connection. J Korean Acad Prosthodont 2005;43(3):352-62

44. **Conrad HJ, Pesun IJ, DeLong R, Hodges JS.** Accuracy of two impression techniques with angulated implants. J Prosthet Dent 2007;97:349-56

45. **Daoudi MF, Setchell DJ, Searson LJ.** An evaluation of three implant level impression techniques for single tooth implant. Eur J Prosthodont Restor Dent 2004;12(1):9–14.

46. **Del'Acqua MA, Arioli-Filho JN, Compagnoni MA, Mollo Fde A Jr.** Accuracy of impression and pouring techniques for an implant-supported prosthesis. Int J Oral Maxillofac Implants 2008 Mar-Apr;23(2):226-36.

47. **Del'Acqua MA, Chavez AM, Compagnoni MA, Assis Mollo F.** Accuracy of impression techniques for an implant supported prosthesis. Int J Oral Maxillofac Implants 2010;25:715-21

48. **Del'Acqua MA, Chavez AM, Castanharo SM, Compagnoni MA, Assis Mollo F.** The effect of splint material rigidity in implant impression techniques. Int J Oral Maxillofac Implants 2010;25:1153-58

49. **Deogade SC, Dube G.** A sectional-splinting technique for impressing multiple implant units by eliminating the use of an open tray. Contemp Clin Dent 2014 Apr;5(2):221-6.

50. **Di Fiore A, Meneghello R, Savio G, Sivolella S, Katsoulis J, Stellini E.** In Vitro Implant Impression Accuracy Using a New Photopolymerizing SDR Splinting Material. Clin Implant Dent Relat Res 2015 Oct;17 Suppl 2:e721-9.

51. **Dumbrigue HB, Gurun DC, Javid NS.** Prefabricated acrylic resin bars for splinting implant transfer copings. J Prosthet Dent 2000;84:108-110

52. **Elias CN.** Factors affecting the success of dental implants. Implant Dentistry 2004:319-64

53. **Elshenawy EA, Alam-Eldein AM, Abd Elfatah FA.** Cast accuracy obtained from different impression techniques at different angulations (in vitro study) Int J Implant Dent 2018;4(9):01-09

54. **El Osta N, El Osta L, Moukaddem F, Papazian T, Saad R, Hennequin M, Rabbaa Khabbaz L.** Impact of implant-supported prostheses on nutritional status and oral health perception in edentulous patients. Clin Nutr ESPEN 2017 Apr;18:49-54.

55. **Faria JCB, Silva-Concílio LR, Neves ACC, Miranda ME, Teixeira ML.** Evaluation of the accuracy of different transfer impression techniques for multiple implants. Braz Oral Res 2011 Mar-Apr;25(2):163-7.

56. **Filho HG, Mazaro JV, Vedovatto E, Assunção WG, dos Santos PH.** Accuracy of impression techniques for implants. Part 2 - comparison of splinting techniques. J Prosthodont 2009 Feb;18(2):172-6.

57. **Gallucci GO, Papaspyridakos P, Ashy LM, Kim GE, Brady NJ, Weber HP.** Clinical accuracy outcomes of closed tray and open tray implant impression techniques for partially edentulous patients. Int J Prosthodont 2011;24:469-72

58. **Gjengedal H, Dahl L, Lavik A et al.** Randomized clinical trial comparing dietary intake in patients with implant-retained overdentures and conventionally relined denture. Int J Prosthodont 2012;25:340–7.

59. **Hariharan R, Shankar C, Rajan M, Baig MR, Azhagarasan NS.** Evaluation of accuracy of multiple dental implant impressions using various splinting materials. Int J Oral Maxillofac Implants 2010;25:38–44.

60. **Hebel KS, Galindo D, Gajjar RC.** Implant position record and implant position cast: minimizing errors, procedures and patient visits in the fabrication of the milled-bar prosthesis. J Prosthet Dent 2000 Jan;83(1):107-16.

61. **Herbst D, Nel JC, Driessen CH, Becker PJ.** Evaluation of impression accuracy for osseointegrated implant supported superstructures. J Prosthet Dent 2000 May;83(5):555-61.

62. **Hickey JC, Zarb GA.** Boucher's Prosthodontic treatment for edentulous patients. Biomechanics of edentulous state. 9 th ed. New Delhi: CBS Publishers; 1990. p. 6-7

63. **Hsu CC, Millstein PL, Stein RS.** A comparative analysis of the accuracy of implant transfer techniques. J Prosthet Dent 1993;69:588–593.

64. **Hsu ML, Chung TF, Kao HC.** Clinical implications of angled abutments-a literature review. Chin Dent J 2005;24(1):15-20

65. **Humphries RM, Yaman P, Bloem TJ.** The accuracy of implant master casts constructed from transfer impressions. Int J Oral Maxillofac Implants 1990;5:331–336.

66. **Ibrahim TO, Ghuneim WA.** Composite resin versus two different splinting techniques on evaluation of impression accuracy for dental implants. Life Sci J 2013; 10(12s):1013-18

67. **Inturregui JA, Aquilino SA, Ryther JS, Lund PS.** Evaluation of three impression techniques for osseointegrated oral implants. J Prosthet Dent 1993;69:503–509.

68. **Jayasinghe RM, Jayasinghe JAVP, Thilakumara IP.** Prosthetic rehabilitation of edentulous mandible: conventional vs. implant supported prostheses. Sri Lanka Dent J 2017; 47(03) 49-58.

69. **Jemt T, Rubenstein JE, Carlsson L, Lang BR.** Measuring fit at the implant prosthodontic interface. J Prosthet Dent. 1996 Mar;75(3):314-25.

70. **Jo SH. Kim KI, Seo JM, Song KY, Park JM, Ahn SG.** Effect of impression coping and implant angulation on the accuracy of implant impressions- an in vitro study. J Adv Prosthodont 2010; 2:128-33

71. **Joseph TM, Ravichandran R, Lylajam S, Viswabharan P, Janardhanan K, Rajeev S.** Evaluation of positional accuracy in multiple implants using four different splinting materials: An in vitro study. J Indian Prosthodont Soc. 2018 Jul-Sep;18(3):239-247.

72. **Kamrani FA, Namazi AM, Hamedy R, Ghadiri P.** Accuracy of an open tray implant impression technique with three splinting materials: An in vitro study. Gen Dent 2014: 62-66

73. **Kan JY, Rungcharassaeng K, Bohsali K, Goodacre CJ, Lang BR.** Clinical methods for evaluating implant framework fit. J Prosthet Dent. 1999 Jan;81(1):7-13.

74. **Karbach J, Hartmann S, Jahn-Eimermacher A, Wagner W.** Oral health-related quality of life in edentulous patients with two- vs four-locator-retained mandibular overdentures: a prospective, randomized, crossover study. Int J Oral Maxillofac Implants 2015 Oct;30(5):1143e8.

75. **Katsoulis J, Takeichi T, Sol Gaviria A, Peter L, Katsoulis K.** Misfit of implant prostheses and its impact on clinical outcomes. Definition,

assessment and a systematic review of the literature. Eur J Oral Implantol 2017;10 Suppl 1:121-138.

76. **Kim KS.** Biomechanical comparison of axial and tilted implants for mandibular full arch fixed prosthesis. Int J Oral Maxillofac Implants. 2011; 26:976-84

77. **LaBarge KW.** Electrical discharge machining. J Dent Technol 1997;14:19-22.

78. **Lee H, So JS, Hochstedler JL, Ercoli C.** The accuracy of implant impressions: a systematic review. J Prosthet Dent. 2008 Oct;100(4):285-91.

79. **Lee HJ, Lim YJ, Kim CW, Choi JH, Kim MJ.** Accuracy of a proposed implant impression technique using abutments and metal framework. J Adv Prosthodont. 2010 Mar;2(1):25-31.

80. **Lee SJ, Cho SB.** Accuracy of five implant impression technique: effect of splinting materials and methods. J Adv Prosthodont. 2011 Dec;3(4):177-85.

81. **Lee YJ, Heo SJ, Koak JY, Kim SK.** Accuracy of different impression techniques for internal-connection implants. Int J Oral Maxillofac Implants. 2009 Sep-Oct;24(5):823-30.

82. **Leggat PA, Kedjarune U, Smith DR.** Toxicity of cyanoacrylate adhesive and their occupational impacts for dental staffs. Industrial Health. 2004;42:207-11

83. **Linehan AD, Windeler AS.** Passive fit of implant-retained prosthetic framework improved by electric discharge machining. J Prosthodont 1994;3:88-95.

84. **Loos LG.** A fixed prosthodontic technique for mandibular osseointegrated titanium implants. J Prosthet Dent. 1986 Feb;55(2):232-42.

85. **Lopes-Júnior I, de Lima Lucas B, Gomide HA, Gomes VL.** Impression techniques for multiple implants: a photoelastic analysis. Part I: comparison of three direct methods. J Oral Implantol. 2013 Oct;39(5):539-44.

86. **Madhan R, Nayar S, Annapoorani H.** Comparative evaluation of accuracy of six different implant impression techniques: An in vitro study. J Indian Prosthodont Soc 2006;6:185-9

87. **Malo P, Rangert B, Nobre M. "**All-on-4" Immediate function concept with Branemark system implants for completely edentulous mandibles: A retrospective clinical study. Clin Implant Dent Relat Res. 2003;5(Suppl 1):2-9

88. **Marinis A, Afshari FS, Yuan JC-C, Lee DJ, Syros G, Knoernschild KL, et al.** Retrospective analysis of implant overdenture treatment in the advanced prosthodontic clinic at the University of Illinois at Chicago. J Oral Implantol 2016 Feb;42(1):46e53

89. **Martínez-Rus F, García C, Santamaría A, Özcan M, Pradíes G.** Accuracy of definitive casts using 4 implant-level impression techniques in a scenario of multi-implant system with different implant angulations and subgingival alignment levels. Implant Dent. 2013 Jun;22(3):268-76.

90. **Mojon P, Oberholzer J, Meyer JM, Belser UC.** Polymerization shrinkage of index and pattern acrylic resins. *J Prosthet Dent*. 1990;64:684-688.

91. **Mostafa TM, Elgendy MN, Kashef NA, Halim MM.** Evaluation of the precision of three implant transfer impression techniques using two elastomeric impression materials. Int J Prosthodont 2010;23:525–528.

92. **Mpikos P, Kafantaris N, Tortopidis D, Galanis C, Kaisarlis G, Koidis P.** The effect of impression technique and implant angulation on the

impression accuracy of external- and internal-connection implants. Int J Oral Maxillofac Implants. 2012 Nov-Dec;27(6):1422-8.

93. **Naconecy MM, Teixeira ER, Shinkai RS, Frasca LC, Cervieri A.** Evaluation of the accuracy of 3 transfer techniques for implant-supported prostheses with multiple abutments. Int J Oral Maxillofac Implants. 2004 Mar-Apr;19(2):192-8.

94. **Nakhaei M, Madani AS, Moraditalab A, Haghi HR.** Three-dimensional accuracy of different impression techniques for dental implants. Dent Res J (Isfahan). 2015;12(5):431-7.

95. **N'gom PI, Woda A.** Influence of impaired mastication on nutrition. J Prosthet Dent 2002 Jun;87(6):667e73.

96. **Nissan J, Barnea E, Krauze E, et al.** Impression technique for partially edentulous patients. J Prosthet Dent. 2002; 88:103-104.

97. **Nobel Biocare.** All on four treatment concept procedures manual

98. **Ongul D, Gokcen-Rohlig B, Sermet B, Keskin H.** A comparative analysis of the accuracy of different direct impression techniques for multiple implants. Aust Dent J 2012;57:184–189.

99. **Palifique universal flow,** technical report ver. 1. Tokuyama dental

100. **Palifique universal bond-** self cured universal adhesive catalog. Tokuyama dental.

101. **Palifique universal bond,** technical report ver. 1.2. Tokuyama dental corp. 2017.07.20

102. **Papaspyridakos P, Kim YJ, Finkelman M, El-Rafie K, Weber HP.** Digital Evaluation of Three Splinting Materials Used to Fabricate

Verification Jigs for Full-Arch Implant Prostheses: A Comparative Study. J Esthet Restor Dent 2017 Apr;29(2):102-109.

103. **Parameshwari G, Chittaranjan B, Sudhir N, Anulekha-Avinash CK, Taruna M, Ramureddy M.** Evaluation of accuracy of various impression techniques and impression materials in recording multiple implants placed unilaterally in a partially edentulous mandible- An in vitro study. J Clin Exp Dent. 2018 Apr 1;10(4):e388-e395.

104. **Pennington J, Parker S**. Improving quality of life using removable and fixed implant prostheses. Compend Contin Educ Dent Jamesbg N J 1995 2012 Apr;33(4):268e70. 272, 274e6

105. **Phillips KM, Nicholls JI, Ma T, Rubenstein J.** The accuracy of three implant impression techniques: a three-dimensional analysis. Int J Oral Maxillofac Implants 1994;9:533–540.

106. **Prasad A, Rao L.** Comparative evaluation of dimensional accuracy of impression techniques for parallel implants and implants placed with angulation: an in vitro study. Int J Oral Implantol Clin Res 2014; 5(3): 92-98.

107. **Prithviraj DR, Malesh L. Pujari, Pooja Garg, D.P. Shruthi.** Accuracy of the implant impression obtained from different impression materials and techniques: review. J Clin Exp Dent, 2011;3(2):e106-11.

108. **Pujari M, Garg P, Prithviraj DR.** Evaluation of accuracy of casts of multiple internal connection implant prosthesis obtained from different impression materials and techniques: an in vitro study. J Oral Implantol. 2014 Apr;40(2):137-45.

109. Reddy S, Prasad K, Vakil H, Jain A, Chowdhary R. Accuracy of impressions with different impression materials in angulated implants. Niger J Clin Pract. 2013 Jul-Sep;16(3):279-84.

110. Riedy SJ, Lang BR, Lang BE. Fit of implant frameworks fabricated by different techniques. J Prosthet Dent. 1997 Dec;78(6):596-604.

111. Rutkunas V, Ignatovic J. A technique to splint and verify the accuracy of implant impression copings with light-polymerizing acrylic resin. J Prosthet Dent. 2014 Mar;111(3):254-6.

112. Saboury A, Neshandar Asli H, Dalili Kajan Z. The Accuracy of Four Impression-making Techniques in Angulated Implants Based on Vertical Gap. J Dent (Shiraz). 2017 Dec;18(4):289-297.

113. Sahin S, Cehreli MC. The significance of passive framework fit in implant prosthodontics: current status. Implant Dent. 2001;10:85–92.

114. Schmitt SM, Chance DA. Fabrication of titanium implant-retained restorations with nontraditional machining techniques. Int J Prosthodont 1995;8:332-6.

115. Selvaraj S, Dorairaj J, Mohan J, Simon P. Comparison of implant cast accuracy of multiple implant impression technique with different splinting materials: An in vitro study. J Ind Prosthodont Soc 2016;16(2):167-75

116. Shankar YR, Sahoo S, Hari Krishna M, Kumar PS, Kumar TS, Narula S. Accuracy of implant impressions using various impression techniques and impression materials. J Dent Implants 2016; 6(1):29-36

117. Skalak R. Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent. 1983 Jun;49(6):843-8.

118. **Smith B, Baysan A, Fenlon M.** Association between oral health impact profile and general health scores for patients seeking dental implants. J Dent 2009 May;37(5):357e9.

119. **Sorrentino R, Gherlone EF, Calesini G, Zarone F.** Effect of implant angulation, connection length, and impression material on the dimensional accuracy of implant impressions: an in vitro comparative study. Clin Implant Dent Relat Res. 2010 May;12 Suppl 1:e63-76.

120. **Soto-Penaloza D, Zaragozí-Alonso R, Penarrocha-Diago M, Penarrocha-Diago M.** The all-on-four treatment concept: Systematic review. J Clin Exp Dent. 2017 Mar 1;9(3):e474-e488.

121. **Spector MR, Donovan TE, Nicholls JI.** An evaluation of impression techniques for osseointegrated implants. J Prosthet Dent. 1990 Apr;63(4):444-7.

122. **Steigenga JT, al-Shammari KF, Nociti FH, Misch CE, Wang HL.** Dental implant design and its relationship to long-term implant success. Implant Dent. 2003;12(4):306-17.

123. **Stimmelmayr M, Güth JF, Erdelt K, Happe A, Schlee M, Beuer F.** Evaluation of impression accuracy for a four implant mandibular model – a digital approach. Clin Oral Invest 2012; 16:1137-1142

124. **Stimmelmayr M, Güth JF, Erdelt K, Happe A, Schlee M, Beuer F**. Clinical study evaluating the discrepancy of two different impression techniques of four implants in an edentulous jaw. Clin Oral Invest 2013 Nov;17(8):1929-35.

125. **Tarib NA, Seong TW, Chuen KM, Kun MS, Ahmad M, Kamarudin KH.** Evaluation of splinting implant impression techniques: two dimensional analyses. Eur J Prosthodont Restor Dent 2012 Mar;20(1):35-9.

126. **Taruna M, Chittaranjan B, Sudheer N, Tella S, Abusaad MD.** Prosthodontic Perspective to All-On-4® Concept for Dental Implants. J Clin Diagn Res 2014 Oct; 8(10): ZE16–ZE19.

127. **Tasneem Begg.** Stress patterns around distal angled implants in the all-on-four concept configuration. Int J Oral Maxillofac Implants 2009;24:663-671.

128. **Tricio, J., van Steenberghe, D., Rosenburg, D. & Duchateau, L.** Implant stability related to insertion torque force and bone density: An invitro study. J Prosthet Dent 1995;74:608–612.

129. **Vigolo P, Majzoub Z, Cordioli G.** In vitro comparison of master cast accuracy for single-tooth implant replacement. J Prosthet Dent. 2000 May;83(5):562-6.

130. **Vigolo P, Fonzi F, Majzoub Z, Cordioli G.** Evaluation of the accuracy of three techniques used for multiple implant abutment impressions. J Prosthet Dent 2003;89:186-92

131. **Vigolo P, Fonzi F, Majzoub Z, Cordioli G.** An evaluation of impression techniques for multiple internal connection implant prostheses. J Prosthet Dent. 2004 Nov;92(5):470-6.

132. **Vigolo P, Mutinelli S, Fonzi F, Stellini E.** An in-vitro evaluation of impression techniques for multiple internal and external connection implant prostheses. Quintessence Pub. Int J Oral Maxillofac Implants 2014; 29(4):807-18

133. **Vojdani M, Torabi K, Ansarifard E.** Accuracy of different impression materials in parallel and nonparallel implants. Dent Res J (Isfahan). 2015 Jul-Aug;12(4):315-22.

134. **Wee AG, Aquilino SA, Schneider RL.** Strategies to achieve fit in implant prosthodontics- A review of literature. Int J Prosthodont 1999;12:167-78

135. **Wee AG.** Comparison of impression materials for direct multiimplant impressions. J Prosthet Dent 2000;83:323–331.

136. **Zarb GA, Janson T. Prosthodontic procedure. In:Branemark P-I, Zarb GA, Albrektsson T, editors.** Tissue-integrated prostheses: osseointegration in clinical dentistry. Chicago (IL): Quintessence Publ; 1985, pp. 241–82.

ANNEXURE IV

PLAGIARISM REPORT

URKUND

Urkund Analysis Result

Analysed Document: URKUND.docx (D47644858)
Submitted: 2/6/2019 10:46:00 AM
Submitted By: jensysg21@gmail.com
Significance: 1 %

Sources included in the report:

plagarism check.docx (D34339970)
Ganagamani.docx (D46455972)
https://www.researchgate.net/publication/5590242_Effect_of_subgingival_depth_of_implant_placement_on_the_dimensional_accuracy_of_the_implant_impression_An_in_vitro_study
http://www.j-ips.org/viewimage.asp?img=JIndianProsthodontSoc_2016_16_2_167_167937_f12.jpg

Instances where selected sources appear:

6